Appendix A

Total Maximum Daily Loads of Nitrogen for Three Tidal Tributaries and Total Maximum Daily Load of Biochemical Oxygen Demand for One Tributary in the Newport Bay System Worcester County, Maryland

FINAL

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MODELING FRAMEWORK

The computational framework chosen for the modeling of water quality in Newport Bay was the Water Quality Analysis Simulation Program version 5.1 (WASP5.1). WASP5.1 is supported and distributed by U.S. Environmental Protection Agency's (EPA) Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al,* 1993). This program provides a generalized framework for modeling contaminant fate and transport in surface waters (Di Toro *et al*, 1993) and is based on the finite-segment approach. It is a very versatile program, capable of being applied in a time-variable or steady-state mode, spatial simulation in one, two or three dimensions, and using linear or non-linear estimations of water quality kinetics. To date, WASP5.1 has been employed in many modeling applications that have included river, lake, estuarine and ocean environments. The model has been used to investigate water quality concerns regarding dissolved oxygen (DO), eutrophication, and toxic substances. WASP5.1 has been used in a wide range of applications by regulatory agencies, consulting firms, academic researches, and others. EUTRO5.1 is the component of WASP5.1 that is applicable for modeling eutrophication, incorporating eight water quality constituents in the water column (Figure A1) and sediment bed.

The Newport Bay Eutrophication Model (NBEM) based on a EUTRO5.1 model was implemented in a steady-state mode. This mode of using WASP5.1 simulates constant flow and average waterbody volume over the tidal cycle. The tidal mixing is accounted for using dispersion coefficients, which quantify the exchange of water quality constituents between EUTRO5.1 model segments. The model simulates an equilibrium state of the waterbody, which was applied to summer flow, spring flow and the winter flow conditions. These cases are described in more detail below.

WATER QUALITY MONITORING

All readily available information was considered in this TMDL analysis. Several sources of recent water quality data were particularly useful in supporting the model calibration: Maryland Department of the Environment (MDE) (1998), Department of Natural Resources (DNR) (1998-1999), Maryland Coastal Bays Program (MCBP) (1997-2000), and National Park Service (NPKS) (1991-1999). MDE's Field Operations Program staff collected physical and chemical samples in the spring and the summer of 1998. The physical parameters, DO, salinity, conductivity, and water temperature were measured *in situ* at each water quality monitoring station. Grab samples were also collected for laboratory analysis. The samples were collected at a depth of 0.5 m from the surface. Samples were placed in plastic bottles and preserved on ice until they were delivered to the University of Maryland Laboratory in Solomons, MD, or the Department of Health & Mental Hygiene in Baltimore, MD for analysis. The field and laboratory protocols used to collect and process the samples are summarized in Table A1 (MDE, April 2001).

The DNR data was collected as part of their *Pfisteria* monitoring program. The laboratory protocols are similar to those used by MDE. The MCBP maintains a volunteer monitoring program. The sampling and laboratory protocols used by the MCBP are explained in "Coastal

Bays Volunteer Monitoring Program, Water Quality Monitoring Manual Maryland Coastal Bays Program, 1997." The NPKS maintains a monitoring program in coordination with DNR's *Pfisteria* network, shellfish program and the brown tide program, and its protocol is similar to those used by MDE. Table A2 shows the sampling dates for the data sets from the four programs. Figure A2 shows the locations of the sampling stations. Figures A3 – A7 show the high flow and low flow data for chlorophyll *a*, DO, dissolved inorganic nitrogen, dissolved inorganic phosphorus, and biochemical oxygen demand (BOD) (low flow only, no BOD data was collected during high flow).

The eutrophication model is calibrated for both high flow and low flow periods. Temporal and spatial data availability as well as temperature and flow measurements were examined to determine the appropriate data to include as part of each calibration. Comprehensive data, that covered both tidal and non-tidal waters, was limited to 1998. Due to this limited data availability, the time period chosen for each of the calibrations focused on this time period. MDE and DNR both collected data in the tributaries that drain to Newport Bay. The MCBP and NPKS both collected near-shore samples for the bay. The model used for Newport Bay is a steady-state depth averaged model, with relatively large segments. The high flow calibration of the model was performed with data from April of 1998 (MDE 4/15, 4/22, 4/29; DNR 4/29; NPKS 1/20, 2/9, 3/13, 4/13, 12/16). The low flow calibration of the model was performed with data from July, August, September and October1998 (MDE 8/12, 9/2; DNR 7/1, 7/28, 8/26, 9/30, 10/21; MCBP 6/17 – 9/24; NPS 5/22 – 9/14).

INPUT REQUIREMENTS [1]

Model Segmentation and Geometry

The spatial domain of the NBEM includes Newport Bay, Kitts Branch, Trappe Creek, Ayer Creek, and Newport Creek. The domain extends from the confluence of Sinupuxent Bay to the upper reaches of Kitts Branch, covering all the point sources in the Newport Bay System. Following a review of the bathymetry for Newport Bay, the system was divided into 27 segments. Figure A8 shows the model segmentation (modeling domain) of the NBEM. Figure A8 also shows the subwatershed segmentation for the Newport Bay watershed. Table A3 lists the segment volumes and depths of the 27 segments. Table A4 lists the characteristic lengths and interfacial areas between segment pairs.

Dispersion Coefficients

The dispersion coefficients were calibrated using the EUTRO5.1 model and in-stream salinity data from 1998. The WASP5.1 model was set up to simulate salinity. As a conservative substance, there are no changes in concentration due to chemical or biological reactions in the water. Thus, concentration is solely determined by mixing. The only sources in the system are

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1 The WASP model requires all input data to be in metric units, and to be consistent with the model, all data in the Appendix will appear in metric units except the river length. Following are several conversion factors to aid in the comparison of numbers in the main document: mgd x (0.0438) = m^3/s | cfs x (0.0283) = m^3/s | lb / (2.2) = kg | mg/l x mgd x (8.34) / (2.2) = kg/d

at the tidal boundaries. For the model execution, salinity values at all boundaries except the tidal boundaries were set to zero. As discussed above, the NBEM was calibrated for two sets of flow conditions, high flow and low flow.

Estimated point and nonpoint source flows for the appropriate flow conditions were included as part of the calibration of the dispersion coefficients. The method used to calibrate the dispersion coefficients is described in more detail below. Figure A9 shows the results of the calibration of the dispersion coefficients for high flow and low flow. The same sets of dispersion coefficients were used for both the high flow and low flow calibrations of the model. The final values of the dispersion coefficients are listed in Table A4.

Freshwater Flows

In 1998, the model calibration period, there were no active U.S. Geological Survey (USGS) gages in the Newport Bay watershed. It was necessary to estimate flows for the "high" flow sampling period (spring), and the "low" flow period (late summer-early fall). These were estimated using an area to flow ratio approach described below. It should be noted that the term "high flow" in this context corresponds to the relatively higher flows observed in spring, and <u>not</u> to rare flood conditions.

The drainage basin was subdivided into 10 subwatersheds (Figure A8). A ratio of flow to area was determined for each subwatershed to estimate the flow from each. The flow to area ratio was calculated based on flow data from the nearby USGS gaging station 01485000 on the Pocomoke River near Willards, Maryland.

The flow ratio, corresponding to "high" (spring-time) flows, was calculated by averaging daily mean stream flow data from April 1 to April 30, 1998, and dividing by the gaged watershed area. The low flow ratio was calculated by averaging daily mean discharge data from July 1 to September 30, 1998, and dividing by the gaged watershed area. Additional sets of flow for 7Q10 conditions, spring flow conditions and winter flow conditions were calculated for use in the model scenarios. An average flow ratio was calculated using the same method as for high and low flow, using discharge data from December 1950 to December 1998. Table A5 presents the flows from each subwatershed for high, low, 7Q10, spring and winter flow conditions. Again, the term "high flow" corresponds to the relatively higher flows that occurred in spring 1998, rather than to high flows from a long-term flow record. In fact, as seen in Table A5, the 1998 "high" flow is estimated to correspond closely to the long-term average flow or spring flow. Table A6 presents the contributing subwatersheds and flows to various water quality segments of the Newport bay model.

Point Source Loadings

<u>Sources Considered</u>

Six point sources were considered in the TMDL analyses. These are the Berlin Wastewater Treatment Plant (WWTP) (MD0022632), Newark WWTP (MD0020630), Kelly Foods Corporation (MD0001309), Tyson Foods Inc. (MD0002071), Ocean City Ice and Seafood

(MD0055107), and Berlin Shopping Center (MD0024911). Berlin Shopping Center is now closed; however, it was considered for the calibration of the model, as it existed during the calibration period. Ocean City Ice and Seafood does not discharge any nutrient loads to the system, but its flow effect has been considered for the modeling purposes. Kelly Foods Corp. is a year-round source, but contributes very little nutrient load to the system. Newark WWTP discharges to the open bay section of the model through a small tributary called Marshall Creek, its effect on the bay itself is minimal, and there is no data collected by MDE to investigate any significant impact of this source to Marshall Creek itself. Recent DNR samplings have revealed DO and algal problems in Marshall Creek. The issue related with this point source will be dealt with at a later date when adequate samplings are available. Only the Berlin WWTP and Tyson Foods, Inc. are major point sources to be considered in the model for significant impact in the development of the model.

Summary of Point Sources Considered

Point Source Name	Modeling Disposition	Discharge/Capacity (mgd)
Berlin Shopping Center WWTP	Considered only for the calibration purposes	0.003
Berlin WWTP	Major source	0.6 – 0.75, current flow
Kelly Foods Corp.	Minor source	0.006
Ocean City Ice and Seafood	Only flow effect considered	0.0015
Newark WWTP	Minor source	0.07
Tyson Foods, Inc.	Major source	0.6 - 0.8, current flow

<u>Model Calibration Consideration of Point Sources</u>

The Berlin WWTP discharges to Trappe Creek through a small tributary called Bottle Branch (model segment 12). Kelly Foods Corp. and Tyson Foods, Inc. both discharge directly to Kitts Branch (model segments 16 and 18 respectively). The flow from Ocean City Ice and Seafood is considered for the modeling purposes as an input to Trappe Creek through Bottle Branch (model segment 12). The Newark WWTP discharges to the open portion of Newport Bay through a small branch called the Marshall Creek (model segment 2). In 1998, the calibration period, these point sources were jointly contributing about 54,818 lbs/yr of nitrogen and 2,251 lbs/yr of phosphorus to the Newport Bay System.

The point source flows and nutrient loadings from all the contributing sources used for the model calibration were calculated from 1998 discharge monitoring reports (DMR) data stored in MDE's Point Source Database (MDE, 2002). The DMR data was supplemented with the comprehensive data provided by John Lister of Tyson Foods Inc. and Randy Danny from the MDE Eastern Shore Field Office. Specifically, the data from April 1998 was used for the high flow calibration of the model. An average of discharge data from July, August, and September of 1998 was used for the low flow calibration of the model. These data are summarized in Table A7.

Model Scenario Consideration of Point Sources

Due to the nature of Newport Bay and changes in the point source operations during different seasons, scenarios are grouped in three categories according to the flow regimes: winter flow (November - March); spring flow (April-May); and summer flow (June – October). For all these flow condition categories, the TMDL analyses consider two primary scenarios: baseline scenarios and TMDL scenarios. Briefly, the baseline scenario for low and average flow conditions simulates a type of no-action situation. Point source flows and loads are increased to planned values with current or anticipated point source treatment technologies. Relatively current land use and nonpoint source loads are simulated, and associated bottom sediment properties are used (e.g., sediment nutrient flux). The TMDL scenarios simulate conditions that correspond to the maximum allowable loads.

Municipal Discharges:

For municipal WWTPs, the baseline scenarios typically assume approved maximum sewer plan flows, and loads that are consistent with planned treatment, and the season simulated by the particular scenario. Berlin Shopping Center is a discontinued source so it is not considered in any of the scenario runs. For the Newark WWTP, the maximum flow and loads were used in both the baseline and the TMDL scenarios for all the flow conditions except summer flow month, when it does not discharge to the bay. Berlin WWTP only discharges during the winter flow month (discharge permitted from November through March only). For the Berlin WWTP, discharge flow of 1.0 mgd was used for both the winter baseline and the winter TMDL scenarios. Table A14 shows the values of other parameters used in all the baseline scenarios for all Municipal Sources. These loads are further summarized in a technical memorandum, which accompanies this TMDL, entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Newport Bay System.*"

Industrial Discharges:

The maximum flow volumes for discharges of industrial effluents directly to waters of the State are not established in local water and sewer plans. Rather, they are established on the basis of need and other considerations. Kelly Foods Corp. (a small point source) has very little effect on the model outputs; therefore, for all the baseline and TMDL scenario runs, this source has been considered at its maximum flow and concentrations. As mentioned earlier, a flow output for Ocean City Ice and Seafood has been considered for all the baseline and the TMDL scenarios. Tyson Foods, Inc. is one significant source that controls almost all of the summer flow and the spring flow output results and the major proportion of the winter flow output result. For both the baseline and TMDL scenarios in the analyses, the Tyson Foods Inc.flow has been considered to be 0.8 mgd. In the baseline scenario the maximum permitted loads for controlled parameters and performing concentrations, loads for non-permitted parameters were used. Table A14 shows the values of other parameters used in all the baseline scenarios for all industrial sources.

The TMDL scenario loads were based on the goals set up for the TMDL. Since the Berlin WWTP (a major source of the TMDL analysis) does not discharge during the summer and spring months, a consideration was given to the carryover effect of the Berlin discharge during winter to the summer and spring months scenario runs. Nutrient fluxes and sediment oxygen demand were adjusted to reflect the changes. These parameters were also adjusted for the reduction of loads for the TMDL. Thus, a key difference between the baseline scenarios and TMDL scenarios, were reductions in sediment nutrient fluxes, and SOD that reflect reduced loads from both the carryover effect, if any, and reductions proposed for point and nonpoint sources. The point source discharges simulated in the TMDL scenarios are summarized in a technical memorandum, which accompanies this TMDL, entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Newport Bay System.*"

Nonpoint Source Loadings

Nonpoint source loads were estimated for observed 1998 "high flow", observed 1998 "low flow", and spring and winter loading conditions. The surface water nonpoint source loads for high flow and low flow conditions were estimated as the product of observed water quality concentrations and the nonpoint source flows estimated as described above. Data from station XCM1562 was used as a boundary condition for segment 1 of the NBEM. The boundary conditions for the remaining non-tidal boundaries (except segments 12 through 19 during high flow) were based on data from station BMC0011. This is the only free-flowing station in the watershed and it was assumed to be a reasonable representation of background water quality in the watershed. Since the station BMC0011 represents mostly a mix of the agriculture and the forest landuses, the average annual load for segments 12 through 19 was used for high flow calibration to represent the predominantly urban watershed segments draining to these water quality segments. BOD data was not available for high flow, and was assumed to be 2.0 mg/l at all boundaries.

The observed concentrations account for surface nonpoint source loads from all land uses, loads from septic tanks, atmospheric deposition to the land's surface, and base-flow groundwater loads. An additional nonpoint source load due to direct atmospheric deposition to the water surface was added to both the high flow and low flow nonpoint source loads used in the calibration of the model. Direct groundwater discharge was included in both the high flow and the low flow calibration of the model. The nonpoint source loads used in the high flow and the low flow calibrations of the model for nitrogen and phosphorus can be seen in Table A8 and Table A9, respectively.

The average annual NPS load estimate was used in both the spring and winter baseline scenarios, and serves as a starting point in determining an estimate of the reduction needed to meet the winter and the spring flow TMDL goals. The average annual loading rates used for the NBEM was derived from the UMCES study *"Maryland's Coastal Bays: An Assessment of Aquatic Ecosystems, Pollutant Loadings, and Management Options."* A detail of the selection of UMCES study as the best option for calculating loading rates in the State's Coastal Bay Region (including Newport Bay) is described in Appendix A of *"Total Maximum Daily Loads of Nitrogen and Phosphorus for Five Tidal Tributaries in the Northern Coastal Bays System Worcester County, Maryland."*

Land use loading rates were derived from the UMCES study described above and applied to the land uses in Newport Bay using a area unit loading rate approach. The land use in Newport Bay was calculated based on 1997 Maryland Department of Planning data, and included an adjustment to cropland acres using 1997 Farm Service Agency (FSA) data. The average annual nonpoint source load was calculated for each of the different loading rate options by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients.

The average annual loading rates used in the final analysis reflect loads coming from urban development, agriculture, and forestland. An additional nonpoint source load due to direct atmospheric deposition to the water surface was included, as well as a load due to direct groundwater discharge. The atmospheric deposition load was calculated by multiplying the surface area of each water quality segment by a loading coefficient. The atmospheric loading coefficient was based on the atmospheric deposition monitoring station MD18, Assateague Island National Seashore – Woodcock established by National Atmospheric Deposition Program.

The direct groundwater loads included in both the high flow and average annual loads were estimated based on methods described in the USGS report *"Ground-Water Discharge and Nitrate Loadings to the Coastal Bays of Maryland"* (Dillow and Greene, 1999). The direct discharge to Newport Bay was separated out from the total by Jonathan Dillow (USGS). The total annual direct discharge load was then distributed to the water quality segments based on the watershed contribution to the individual segments. The direct groundwater load is assumed to account for loads from septic tanks among other sources. The average spring and winter total nitrogen and total phosphorus loads are presented in Table A10 and Table A11, respectively.

For all nonpoint source inputs, the concentrations of the nutrients nitrogen and phosphorus are modeled in their speciated forms. The WASP5.1 model simulates nitrogen as ammonia (NH_3), nitrate and nitrite (NO_{23}), and organic nitrogen (ON); and phosphorus as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algae growth, which can affect chlorophyll *a* levels and DO concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios represent values that have been measured in the field.

Environmental Conditions

Eight environmental parameters were used for developing the model of Newport Bay. They are solar radiation, photoperiod, temperature (T), extinction coefficient (K_e), salinity, sediment oxygen demand (SOD), sediment ammonium flux (FNH_4), and sediment phosphate flux (FPO_4) (Table A12).

The light extinction coefficient, K_e in the water column was derived from Secchi depth measurements using the following equation:

$$K_e = \frac{1.95}{D_s}$$

where:

K_e = light extinction coefficient (m^{-1})
D_s = Secchi depth (m)

Varying SOD, FNH_4, and FPO_4 values were used for different sections of the NBEM segmentation, where "F" indicates these are due to sediment fluxes. Initial values were taken from the Northern Coastal Bay TMDL model and adjusted through the calibration process. Several studies, data sets, and literature sources were reviewed to determine appropriate ranges of values for use with the model: Cerco et al., 1994; Seitzinger and DeKorsey, 1994; Sampou, 1994; Mirsajadi, 2000; UMCES, 1999; Institute of Natural Resources, 1986; and Thomann and Mueller, 1987. All values used in the model are within reasonable ranges predicted to occur in the Newport Bay. In general, lower nutrient flux and SOD values occurred in the open bays, while higher values were assumed in the upper reaches of the tributaries. During the high flow period, cooler temperatures and reduced biological activity reduce the expected nitrogen and phosphorus fluxes from the sediment. Thus, during the high flow period, the simulated ammonium flux and the ortho-phosphate flux were reduced by 75%.

Nonliving organic nutrient components and phytoplankton settle from the water column into the sediment at various rates throughout the system. In general, it is reasonable to assume that 50% of the nonliving organics are in the particulate form. Such assignments were borne out through model sensitivity analyses and were within the range of literature value.

Kinetic Coefficients

The water column kinetic coefficients are universal constants used in the NBEM model. They are formulated to characterize the kinetic interactions among the water quality constituents. The initial values were taken from the eutrophication model developed in the State's Northern Coastal Bay System. Kinetic coefficients from past modeling studies of Potomac River (Clark and Roesh, 1978; Thomann and Fitzpatrick, 1982; Cerco, 1985), and of Mattawoman Creek (Haire and Panday, 1985; Panday and Haire, 1986; Domotor *et al*., 1987), and the Patuxent River (Lung, 1993) were also reviewed. The final kinetic coefficients are listed in Table A13.

Initial Conditions

The initial conditions used in the model were chosen to reflect the observed values as closely as possible. However, because the model simulation was run for a long period of time before it reached equilibrium, it was found that the final results are independent of initial conditions.

CALIBRATION & SENSITIVITY ANALYSES

The NBEM model for low flow was calibrated with July, August and September 1998 data. The NBEM was also calibrated for a high flow period with April 1998 data. Tables A6, A7, and A8 show the point source and nonpoint source flows and loads associated with the input files used for the calibrations of the model (See *Point Source Loadings and Nonpoint Source Loadings* above). Figure A10 shows the results of the low flow calibration of the model for the mainstem and the minor tributaries of Newport Bay. The model has captured the trend of almost all of the state variables with the emphasis on DO to capture the lower range. Ammonia near the middle section near segment 12 seems to be lower, but overall the trend is represented. Figure A11 shows the model results for the high flow calibration of the mainstem and the minor tributaries of Newport Bay. All the major variables are captured well.

Along with the calibration of the high flow and low flow conditions, a series of sensitivity analyses were conducted to analyze the model response to various nutrient loading conditions. The model was found to be responsive to the loads as expected. A comprehensive set of model runs showed that for all seasonal flow and loading conditions the model was limited for change in nitrogen loading. The low flow condition, dominated by the flow from Tyson Foods, Inc., showed that the model was sensitive to change in phosphorus loading at a very low level of phosphorus input.

SYSTEM RESPONSE

The EUTRO5.1 model of Newport Bay was applied to several different nonpoint source loading conditions under various stream flow conditions as described earlier to project the impacts of nutrients on algal production (chlorophyll *a)*, and DO. By simulating various stream flows, the analysis accounts for seasonality.

Model Run Descriptions

<u>The first scenario</u> represents baseline conditions of the stream during summer (low flow). The baseline scenario simulates a type of no-action situation, thus providing a stable point of comparison with the TMDL scenario. Point source flows and loads are increased to maximum planned values under current or anticipated point source treatment technologies. Relatively current land use and nonpoint source loads are simulated, and associated bottom sediment properties are simulated. In this case, the 7Q10 flows were used to present critical conditions during the summer. The flows were estimated using a regression analysis as described above (Table A6). The total nonpoint source loads were computed as the product of observed 1998 base-flow concentrations and the estimated critical low flow with additional loads included to account for direct atmospheric deposition to the water's surface, and the direct groundwater discharge. Because the loads are based on observed concentrations, they account for all natural and human-induced sources.

The point source loads were increased to reflect maximum possible loading conditions under existing or draft permits. The maximum load at Tyson Foods, Inc. was calculated based on the highest loading pattern throughout the year (0.8 mgd), as there is currently no flow limit on the plant. The maximum load at Kelly Foods Corp. was calculated by multiplying the plant's maximum capacity flow by its current National Pollutant Discharge Elimination System (NPDES) permitted concentrations and the reported concentrations for those parameters, which do not have permit values. Flow inputs from Ocean City Ice and Seafood were used as described earlier. All the municipal sources in the basin do not discharge during the summer flow months. The point source loads for Scenario 1 are presented in Table A14. All the environmental parameters and kinetic coefficients established by the low flow calibration of the model remained the same for Scenario 1.

The second scenario represents the baseline conditions of the stream during the spring flow months. The baseline scenario simulates a type of no-action situation, thus providing a stable point of comparison with the TMDL scenario. Point source flows and loads are increased to maximum planned values under current or anticipated point source treatment technologies. Relatively current land use and nonpoint source loads are simulated, and associated bottom sediment properties are assumed. The average annual flows and nonpoint source loads were calculated as described above. The nonpoint source loads included direct groundwater discharge and direct atmospheric deposition to the water's surface. The nonpoint source loads are presented in Table A10.

The point source flows for Tyson Foods, Inc. and Kelly Foods Corp. remained the same as in the Scenario 1. The loads were changed to reflect the annual plant load discharge and permitted load discharge. Berlin WWTP loads were not considered, as it does not discharge during the spring months. Flow from the Newark WWTP was considered. Loads were calculated based on the current flows and loads reflecting permitted conditions. The point source loads used in Scenario 2 can be seen in Table A14. The method used to estimate average annual nitrogen and phosphorus loads did not include estimations of DO, chlorophyll *a*, and BOD boundary loads. The missing values for loadings (BOD, CHL*a*, DO) were assumed to be the same as for the low flow condition. The kinetic coefficients remained the same as for Scenario 1. The environmental parameters, except the temperature, remained the same as Scenario 1. Temperature was changed to reflect average temperature during the spring months (Table A15). The higher solar radiation and temperature during this period represent conservative assumptions as a margin of safety.

The third scenario represents the baseline conditions of the stream during the winter flow months. As explained earlier, the baseline scenario simulates a type of no-action situation, thus providing a stable point of comparison with the TMDL scenario. Point source flows and loads were increased to maximum planned values under current or anticipated point source treatment technologies. Relatively current land use and nonpoint source loads are simulated, and associated bottom sediment properties are assumed. The average annual flows and nonpoint source loads were calculated as described above. The nonpoint source loads included direct groundwater discharge and direct atmospheric deposition to the water surface. The nonpoint source loads are presented in Table A11.

The point source flows and the loads for Tyson Foods, Inc., Kelly Foods Corp. and Newark WWTP remained the same as in the Scenario 2. The Berlin WWTP loads were considered at its requested expansion of the plant (1.0 mgd). Loads were calculated based on the current flow and loads reflecting permitted conditions. The point source loads used in Scenario 3 can be seen in Table A14. The method used to estimate average annual nitrogen and phosphorus loads did not include estimations of DO, chlorophyll *a*, and BOD boundary loads. The missing values for loadings (BOD, CHL*a*, DO) were assumed to be the same as for the high flow condition. The kinetic coefficients remained the same as for Scenario 1. The environmental parameters temperature, fraction of daylight, and solar radiation represent a critical condition in the month of March (Table A15). The higher solar radiation and temperature during this period represent conservative assumptions as a margin of safety.

<u>The TMDL scenarios</u> (Scenario 4, Scenario 5, and Scenario 6) were the result of a number of iterative model scenarios involving nutrient reductions that were explored to determine the maximum allowable loads. The fourth, fifth and sixth scenarios yield the water quality response for the maximum allowable loads for summer flow, spring flow, and winter flow, respectively.

Model sensitivity analyses were performed to ascertain whether the model predicted nitrogen or phosphorus to limit algal growth during the different flow regimes. Under low flow conditions, the model was found to be sensitive to either reduction in phosphorus or nitrogen, indicating a phosphorus-limited/nitrogen-limited system depending on the situation of the loadings. The flow from Tyson Foods, Inc. controls the nutrient limiting situation as the contribution from the non-point source is not that significant to switch the limitation. Under spring and winter flow conditions, the model was not sensitive to reductions in phosphorus, indicating a nitrogen-limited system. These model findings are consistent with nutrient limitation analyses based on the water quality data.

The Berlin WWTP does not discharge during warmer months (i.e., summer and spring flow months). An adjustment was made on the bottom sediment fluxes to account for the no flow effect from this plant. Kelly Foods Corp., a very small source, was not reduced for the TMDL scenario. The Newark WWTP was also set to its current level of discharge as there were not much sampling points to do a detailed analysis for localized problem.

Sediment fluxes were also decreased proportionally in relation to nonpoint and point source load reductions for each scenario. A method was developed to estimate the reductions in nutrient fluxes and SOD from the sediment layer. First, an initial estimate was made of the total organic nitrogen and organic phosphorus settling to the river bottom, from particulate nutrient organics, living algae, and phaeophytin, in each segment. This was done by running the baseline scenario once with estimated settling of organics and chlorophyll *a*, then again with no settling. The difference in the organic matter between the two runs was assumed to settle to the river bottom, where it would be available as a source of nutrient flux and SOD. All phaeophytin was assumed to settle to the bottom. The amount of phaeophytin was estimated from in-stream water quality data. To calculate the organic loads from the algae, it was assumed that the nitrogen to chlorophyll *a* ratio was 6.25, and the phosphorus to chlorophyll *a* ratio was 0.625. This analysis was then repeated for the reduced nutrient loading conditions. The percentage difference between the amount of nutrients that settled in the expected condition scenarios and the amount that settled in the reduced loading scenarios was then applied to the nutrient fluxes in each segment. The reduced nutrient scenarios were then run again with the updated fluxes, with a new value of settled organics and new fluxes calculated. The process was repeated several times, until the reduced fluxes remained constant. Along with reductions in nutrient fluxes from the sediments, when the nutrient loads to the system are reduced, the sediment oxygen demand was also reduced (US EPA, 1997). It was assumed that the SOD would be reduced in the same proportion as the reduction in nitrogen fluxes.

Simulated reductions in nutrients affect the initial concentrations of chlorophyll *a* in the fresh water flows at the model's boundaries. To estimate the chlorophyll *a* reductions, the amount of nitrogen and phosphorus available for algae growth was calculated based on reduced nutrient loads. The maximum possible amount of chlorophyll *a* that could be grown was calculated twice, once assuming nitrogen was the limiting nutrient, and again assuming phosphorus was the limiting nutrient. The lower of two values was compared to the baseline scenario boundary value for chlorophyll *a*, and the lower of these three values was then taken to be the boundary for average flow based on principles of nutrient limitations.

The NBEM calculates the daily average DO concentrations in the stream. This is not necessarily protective of water quality when one considers the effects of diurnal DO variation due to photosynthesis and respiration of algae. The photosynthetic process centers about the chlorophyll *a* containing algae, which utilize radiant energy from the sun to convert water and carbon dioxide into glucose, and release oxygen. Because the photosynthetic process is dependent on solar radiant energy, the production of oxygen proceeds only during daylight hours. Concurrently with this production, however, the algae require oxygen for respiration, which can be considered to proceed continuously. Minimum values of DO usually occur in the early morning predawn hours when the algae have been without light for the longest period of time. Maximum values of DO usually occur in the early afternoon. The diurnal range (maximum minus minimum) may be large. If the daily mean level of DO is low, minimum values of DO during a day may approach zero and create a potential for fish kill. A 1998 study performed on the Pocomoke, captured 24-hour DO measurements from May through September (Boynton and Burger, 1999). This study found that the magnitude of diurnal change in the Pocomoke River was typical of other Chesapeake Bay tributaries, amounting on average to about 2.0 mg/l-day for chlorophyll *a* concentration ranging from 50-100 µg/l and 0.5 mg/l-day for chlorophyll *a* concentration averaging 25 µg/l. Using this as a guideline, the following scenarios include an additional 1.0 mg/l margin of safety to protect for the diurnal variation of DO in the areas of high algal concentration and a 0.3 mg/l margin of safety to protect for the diurnal variation of DO in the areas where the algal concentration averages around 25 µg/l. Thus, the goal for the final scenarios will be a DO concentration of 6 mg/l and 5.3 mg/l, respectively.

<u>The fourth scenario</u> represents improved conditions associated with the maximum allowable loads to the stream during critical low flow (Summer Flow TMDL Scenario). The stream flows, and nonpoint source loads from which reductions were estimated, were the same as baseline Scenario 1. All of the environmental parameters (except sediment nutrient fluxes and SOD) and kinetic coefficients used for the calibration of the model remained the same as baseline Scenario 1.

The nonpoint source load of total nitrogen from runoff was reduced by 45% and the direct atmospheric deposition load of nitrogen to the water's surface was reduced by 20%. It is reasonable to estimate that the direct nitrogen atmospheric deposition loads can be reduced by 20% due to anticipated actions under the Clean Air Act. This is consistent with reductions in the *"TMDL Analysis for Indian River, Indian River Bay, and Rehoboth Bay, Delaware (December, 1998)."*

The point source loads reflect maximum flow expected from the plant. The point source concentration was reduced for nitrogen to 4.0 mg/l for Tyson Foods, Inc. All other sources remained at the same level as the baseline Scenario 2. More information about point source loads can be found in the technical memorandum entitled *"Significant Nutrient and Biochemical*

Oxygen Demand Point and Nonpoint Sources in the Newport Bay System," and in the section entitled *INPUT REQUIREMENTS* above.

The sediment fluxes were adjusted for reduced nonpoint and point source loading condition as mentioned above and the SOD was adjusted accordingly to reflect the changes of fluxes.

In addition to implicit margins of safety discussed below, an explicit margin of safety was included in this scenario. It was computed as 5% of the allowable nonpoint source and direct atmospheric deposition loads.

<u>The fifth scenario</u> represents improved conditions associated with the maximum allowable loads to the stream during spring flow (Spring Flow TMDL Scenario). Under spring flow conditions; the algal growth is nitrogen limited. The stream flows and nonpoint source loads from which reductions were estimated were the same as baseline Scenario 2. All the environmental parameters (except nutrient fluxes and SOD) and kinetic coefficients used for the calibration of the model remained the same as Scenario 2.

The nonpoint source load of total nitrogen from runoff loads were reduced by 45% in the Newport Bay System except Bottle Branch section where a reduction of 55% was made. In addition, the direct atmospheric deposition of nitrogen to the water's surface was reduced by 20% under the assumption that the load reductions will occur throughout the year. Sediment fluxes were reduced based on the method described above.

The point source loads reflect maximum flow expected from the plant. The point source concentration was reduced for nitrogen to 8 mg/l for Tyson Foods, Inc. All other sources stayed at the same level as baseline Scenario 2. More information about point source loads can be found in the technical memorandum entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Newport Bay System*," and in the section entitled *INPUT REQUIREMENTS* above.

In addition to implicit margins of safety discussed below, an explicit margin of safety was included in this scenario. It was computed as 5% of the allowable nonpoint source and direct atmospheric deposition loads.

<u>The sixth scenario</u> represents improved conditions associated with the maximum allowable loads to the stream during high flow (High Flow TMDL Scenario). Under high flow conditions, the algal growth is nitrogen limited. The stream flows, and nonpoint source loads from which reductions were estimated, were the same as baseline Scenario 3. All the environmental parameters (except nutrient fluxes and SOD) and kinetic coefficients used for the calibration of the model remained the same as Scenario 3.

The nonpoint source load of total nitrogen from runoff was reduced by 45% and the direct atmospheric deposition load of nitrogen to the water's surface was reduced by 20%. It is reasonable to estimate that the direct nitrogen atmospheric deposition loads can be reduced by 20% due to anticipated actions under the Clean Air Act. This is consistent with reductions in the

"TMDL analysis for Indian River, Indian River Bay, and Rehoboth Bay, Delaware (December, 1998)."

The point source loads reflect maximum flow expected from the plant. The point source concentration was reduced for nitrogen to 18 mg/l for Tyson Foods, Inc. and 24 mg/l for the Berlin WWTP. All other sources stayed at the same level as baseline Scenario 3. More information about point source loads can be found in the technical memorandum entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Newport Bay System*," and in the section entitled *INPUT REQUIREMENTS* above.

In addition to implicit margins of safety discussed below, an explicit margin of safety was included in this scenario. It was computed as 5% of the allowable nonpoint source and direct atmospheric deposition loads.

Scenario Results

<u>Baseline Scenarios</u>:

1. *Summer Flow (Scenario 1):* Simulates critical low stream flow conditions during summer season. Surface water quality parameters (e.g., nutrient concentrations) are based on 1998 observed data. Additional loads due to direct atmospheric deposition and from the direct groundwater discharge are also included. Point source loads are based on expected flow from the plant and the current operating conditions.

2. *Spring Flow (Scenario 2):* Simulates spring flow conditions, with average annual nonpoint source loads estimated on the basis of 1997 land use, and unit area nutrient loading rates (UMCES, 1993). Point source loads are based on expected flow from the plant and the current operating conditions for the annual condition.

3. *Winter Flow (Scenario 3):* Simulates winter flow conditions, with average annual nonpoint source loads estimated on the basis of 1997 land use, and unit area nutrient loading rates (UMCES, 1993). Point source loads are based on expected flow from the plant and the current operating conditions for the annual condition.

The three baseline scenarios represent the conditions when water quality is impaired by high chlorophyll *a* levels, and low DO concentrations. The results for Scenario 1, Scenario 2, and Scenario 3 can be seen in Figures A12 through A14, respectively.

In Scenario 1 (for low flow conditions), the peak chlorophyll *a* level is around the value of 110 µg/l in the Trappe Creek, which is above the goal of 50 µg/l. The DO level in the Trappe Creek along with Ayer Creek, Newport Creek and Newport Bay are below the analysis threshold of 6.0 mg/l and 5.3 mg/l. Recall that the threshold of 6.0 mg/l is used to account for diurnal variations in DO, where chlorophyll *a* concentrations range from 50-100 µg/l and 5.3 mg/l where the average concentration is below 25 µg/l.

Scenario 2 (for spring flow conditions), shows high chlorophyll *a* values in the Trappe Creek, with values exceeding 107 µg/l. The DO levels are also below the analysis threshold of 6.0 mg/l throughout the Newport Bay, Newport Creek and Ayer Creek.

Scenario 3 (for winter flow conditions), shows high chlorophyll *a* values in the Trappe Creek, with values exceeding 61 µg/l. The DO is above the analysis threshold of 6.0 mg/l throughout the Newport Bay System.

Future Condition TMDL Scenarios:

4. *Summer Flow (Scenario 4):* Simulates the future condition of maximum allowable loads for critical low stream flow conditions during summer season.

5. *Spring Flow (Scenario 5):* Simulates the future condition of maximum allowable loads for spring stream flow conditions.

6. *Winter Flow (Scenario 6):* Simulates the future condition of maximum allowable loads for winter stream flow conditions.

The results of the scenarios indicate that the water quality targets for DO and chlorophyll *a* are satisfied at all locations within the Newport Bay System under consideration in the analysis. The results of Scenario 4 are presented in Figure A12. The results show the standards have been met throughout the bay system under consideration in the analyses. The results of Scenario 5 and Scenario 6 are presented in Figures A13 and A14, respectively. With the desired load reduction as mentioned above, the water quality standards are met throughout the Newport Bay System.

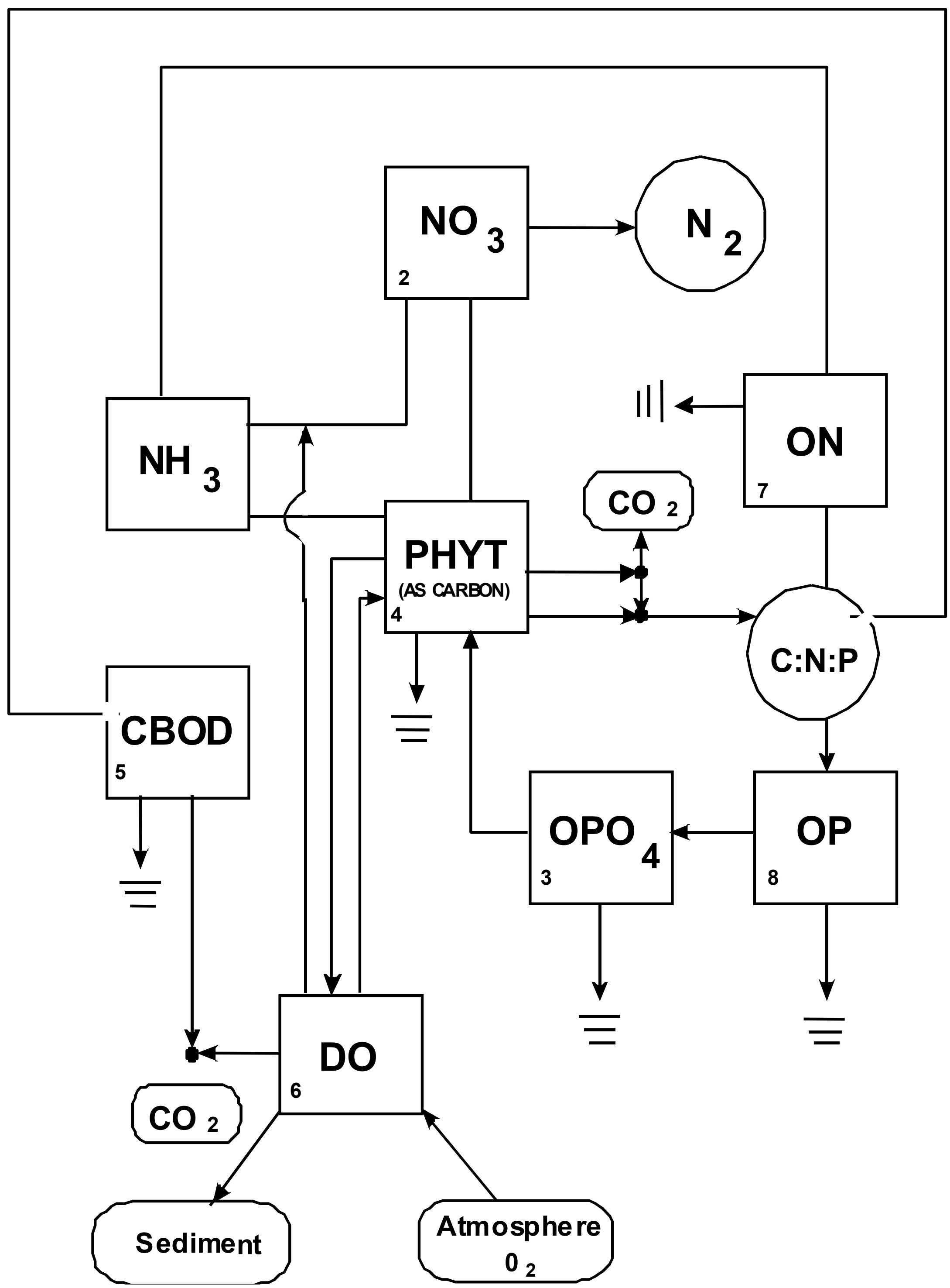

Figure A1: State Variables and Kinetic Interactions in EUTRO5

Table A1: Field and Laboratory Protocols

Parameter	**Units**	**Detection Limits**	Method Reference
IN SITU:			
Flow	cfs	0.01 cfs	Meter (Marsh-McBirney Model 2000 Flo-Mate)
Temperature	degrees Celsius	-5 deg. C to 50 deg. C	Linear thermistor network; Hydrolab Multiparameter Water Quality Monitoring Instruments Operating Manual (1995) Surveyor 3 or 4 (HMWQMIOM)
Dissolved Oxygen	mg/L	0 to 20 mg/l	Au/Ag polargraphic cell (Clark); HMWQMIOM
Conductivity	micro Siemens/cm (μS/cm)	0 to 100,000 μS/cm	Temperature-compensated, five electrode cell Surveyor 4; or six electrode Surveyor 3 (HMWQMIOM)
pH	pH units	0 to 14 units	Glass electrode and Ag/AgCl reference electrode pair; HMWQMIOM
Salinity	ppt	0-70 ppt	Automatic Standard Probe
Secchi Depth	meters	0.1 m	20.3 cm disk
GRAB SAMPLES:			
Ammonium	mg N / L	0.003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrate + Nitrite	mg N / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrite	mg N / L	0.0003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Nitrogen	mg N / L	0.03	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Nitrogen	mg N / L	0.0123	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Ortho-phosphate	mg P / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Phosphorus	mg P / L	0.0015	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Phosphorus	mg P / L		Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Phosphorus	mg P / L	0.0024	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Dissolved Organic Carbon	mg C / L	0.15	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Carbon	mg C / L	0.0759	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Silicate	mg Si / L	0.01	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Suspended Solids	mg / L	2.4	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Chlorophyll *a*	μg/L	1 mg/cu.M	Standard methods for the Examination of Water and Wastewater (15th ed.) #1002G. Chlorophyll. Pp 950-954
BOD_5	mg/l	0.01 mg/l	Oxidation ** EPA No. 405

Table A2: Sampling Dates for Water Quality Data

Sampling Dates	Source
April 15, 1998	MDE
April 22, 1998	MDE
April 29, 1998	MDE
August 12, 1998	MDE
September 2, 1998	MDE
September 30, 1998	MDE
April 29, 1998	DNR
July 1, 1998	DNR
July 28, 1998	DNR
August 26, 1998	DNR
September 30, 1998	DNR
October 21, 1998	DNR
May 1998 to December 1999	MCBP-Volunteer
Long term data from 1991 to 1999	NPS

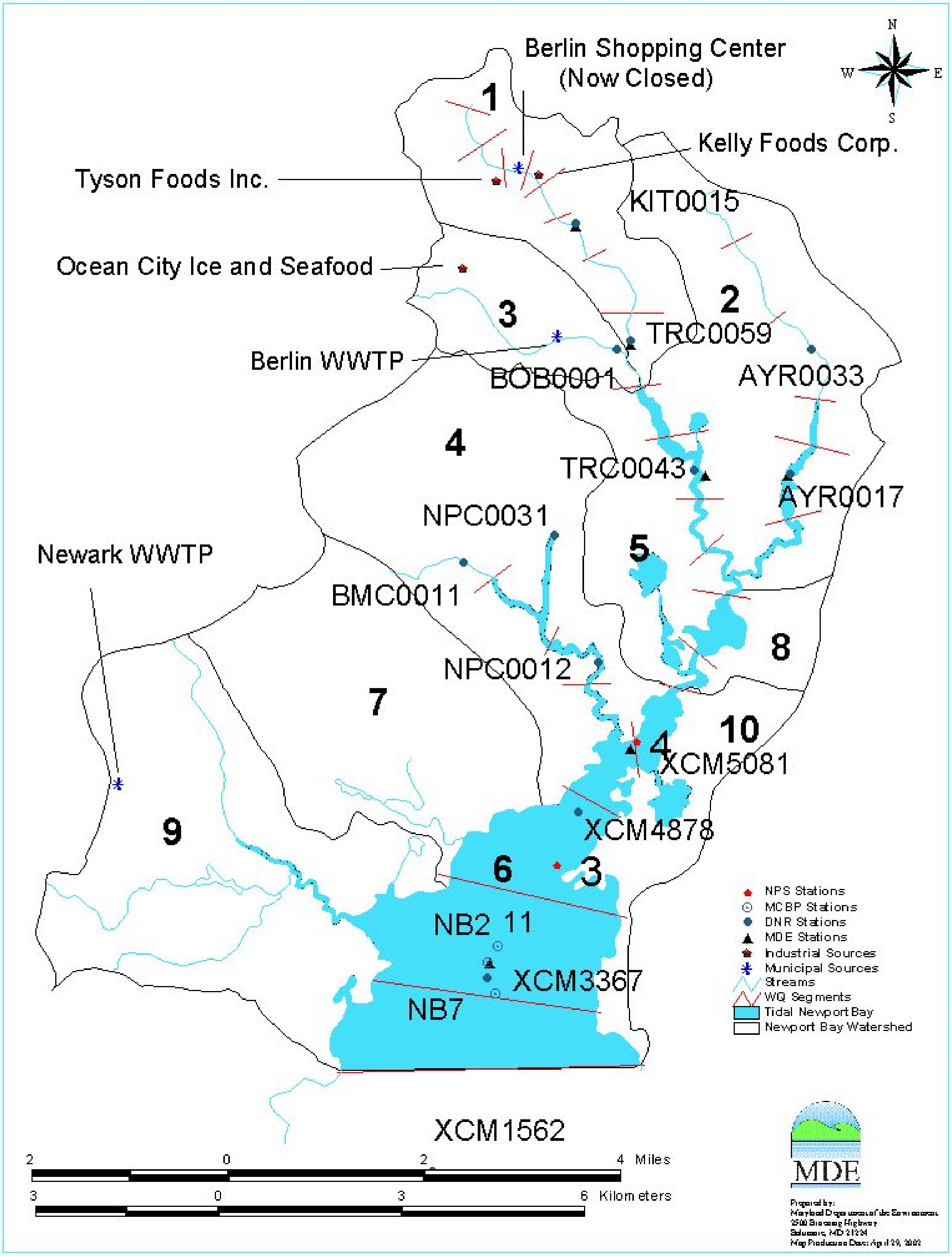

Figure A2: Water Quality Monitoring Stations in the Newport Bay

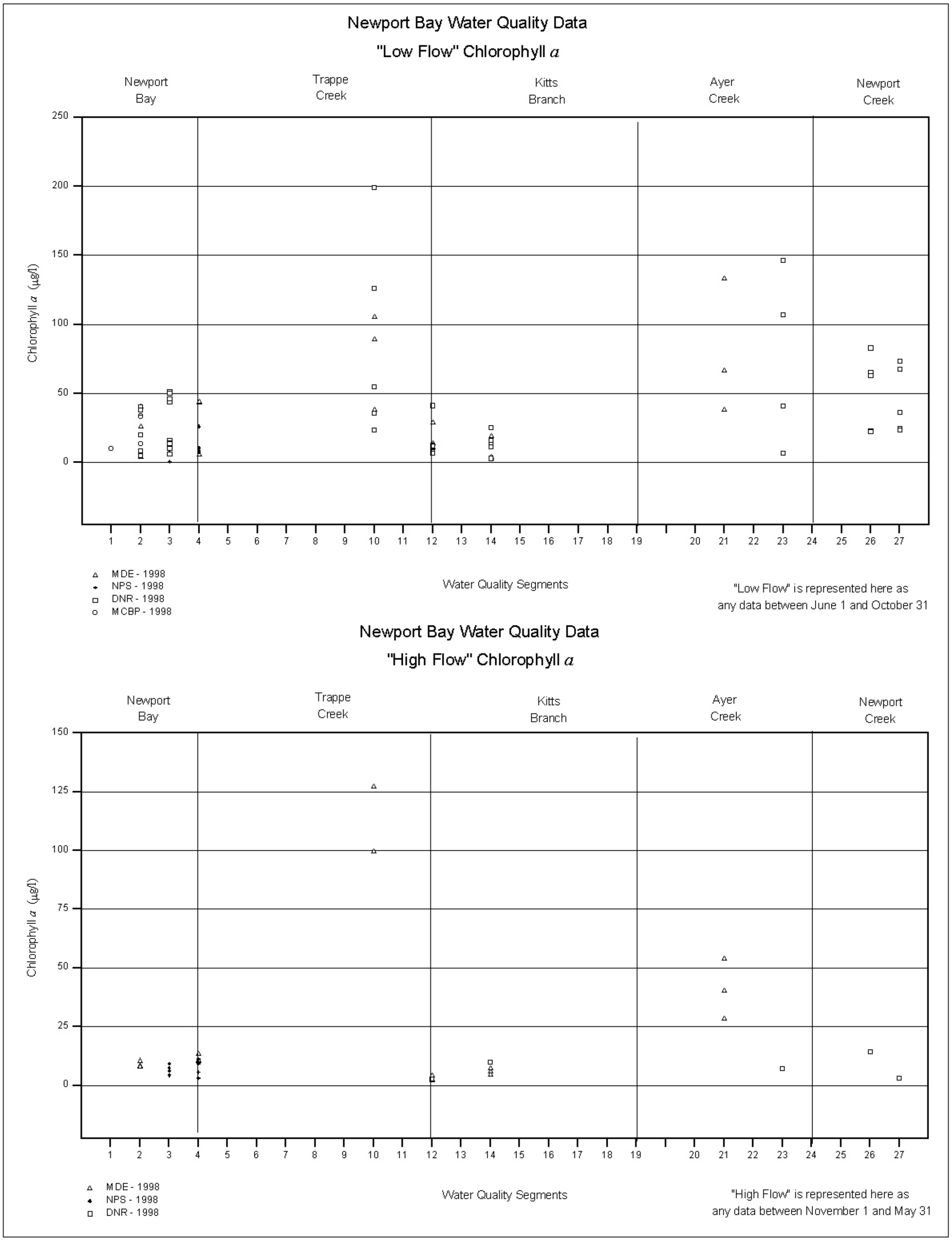

Figure A3: Profile of Chlorophyll *a* Data

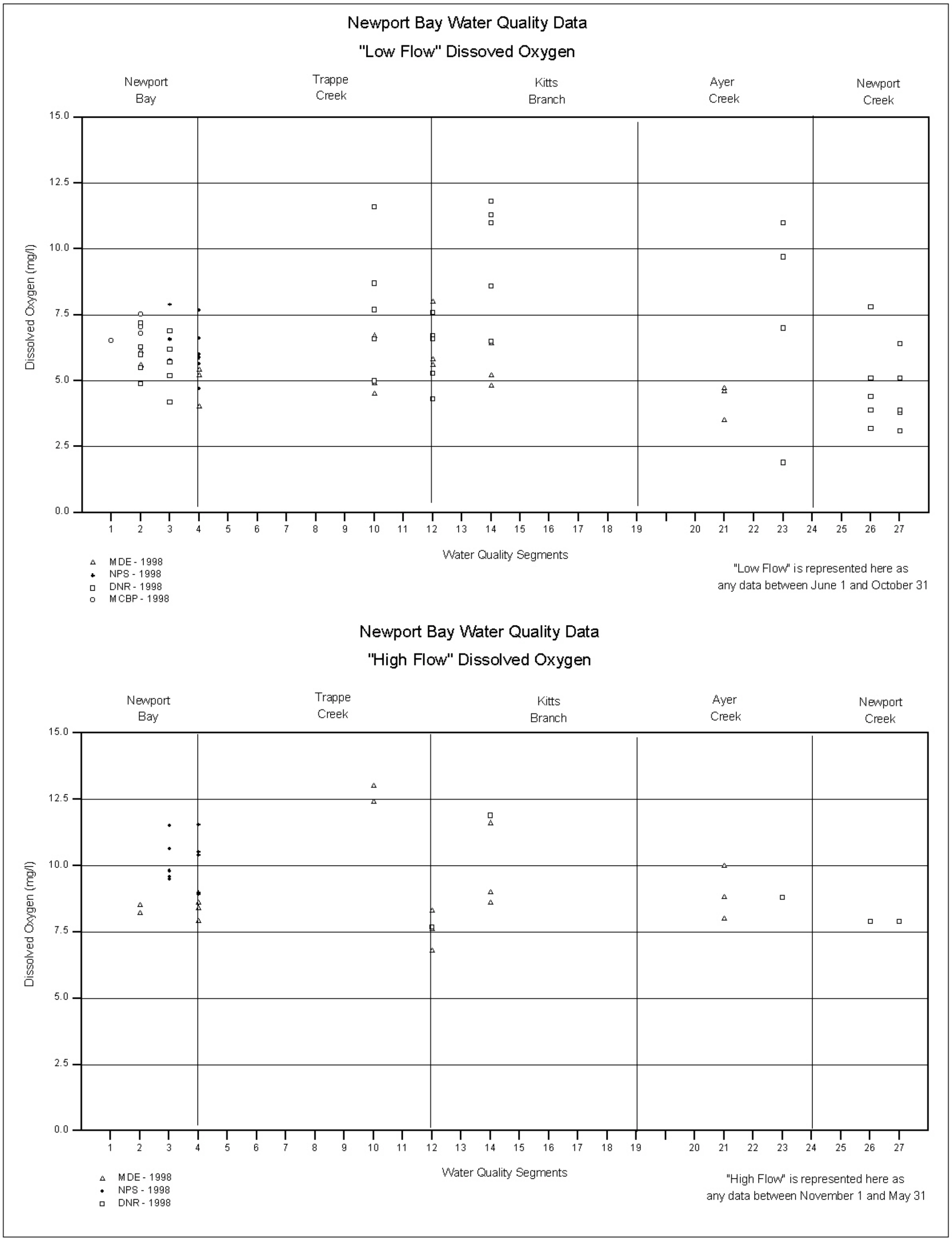

Figure A4: Profile of Dissolved Oxygen Data

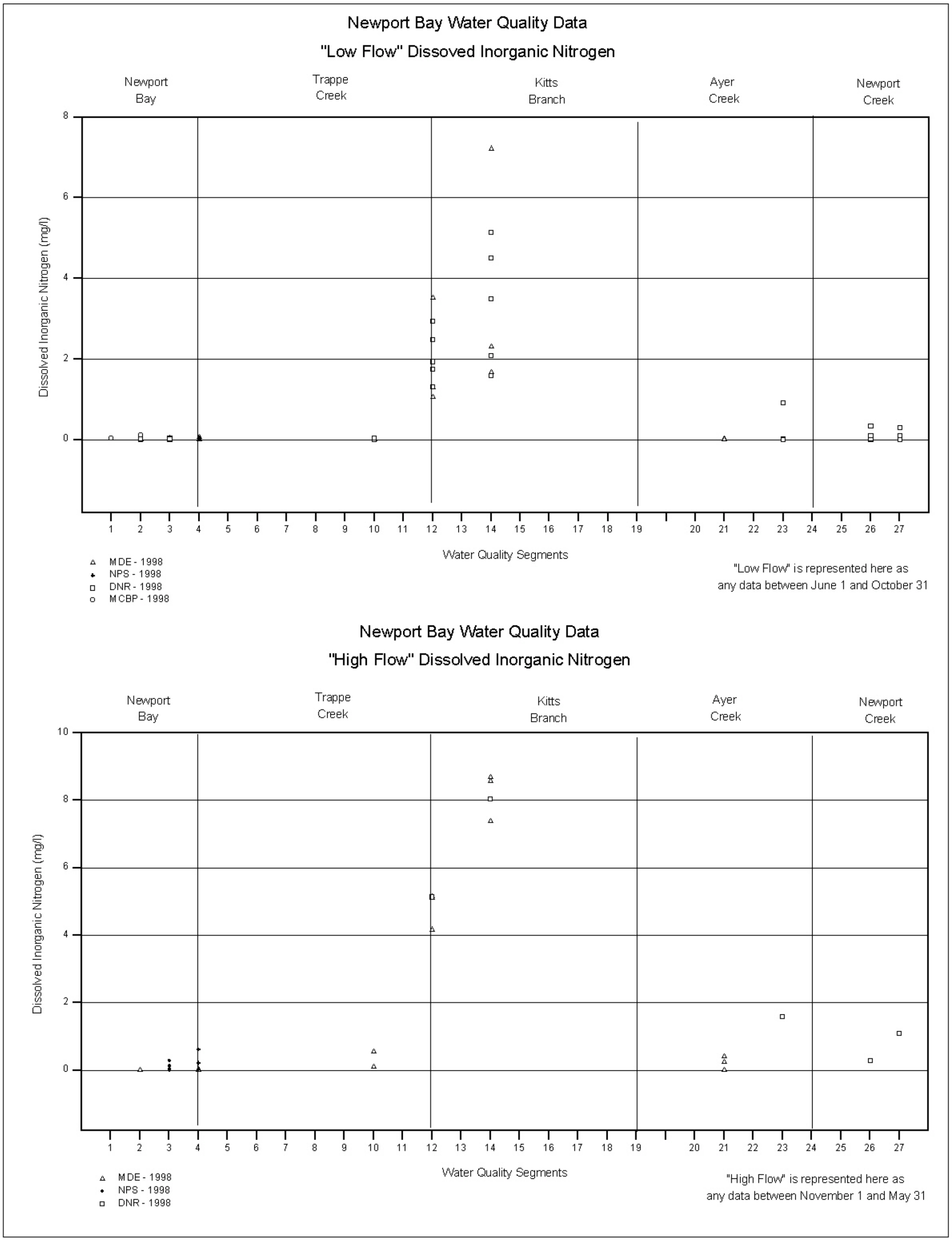

Figure A5: Profile of Dissolved Inorganic Nitrogen Data

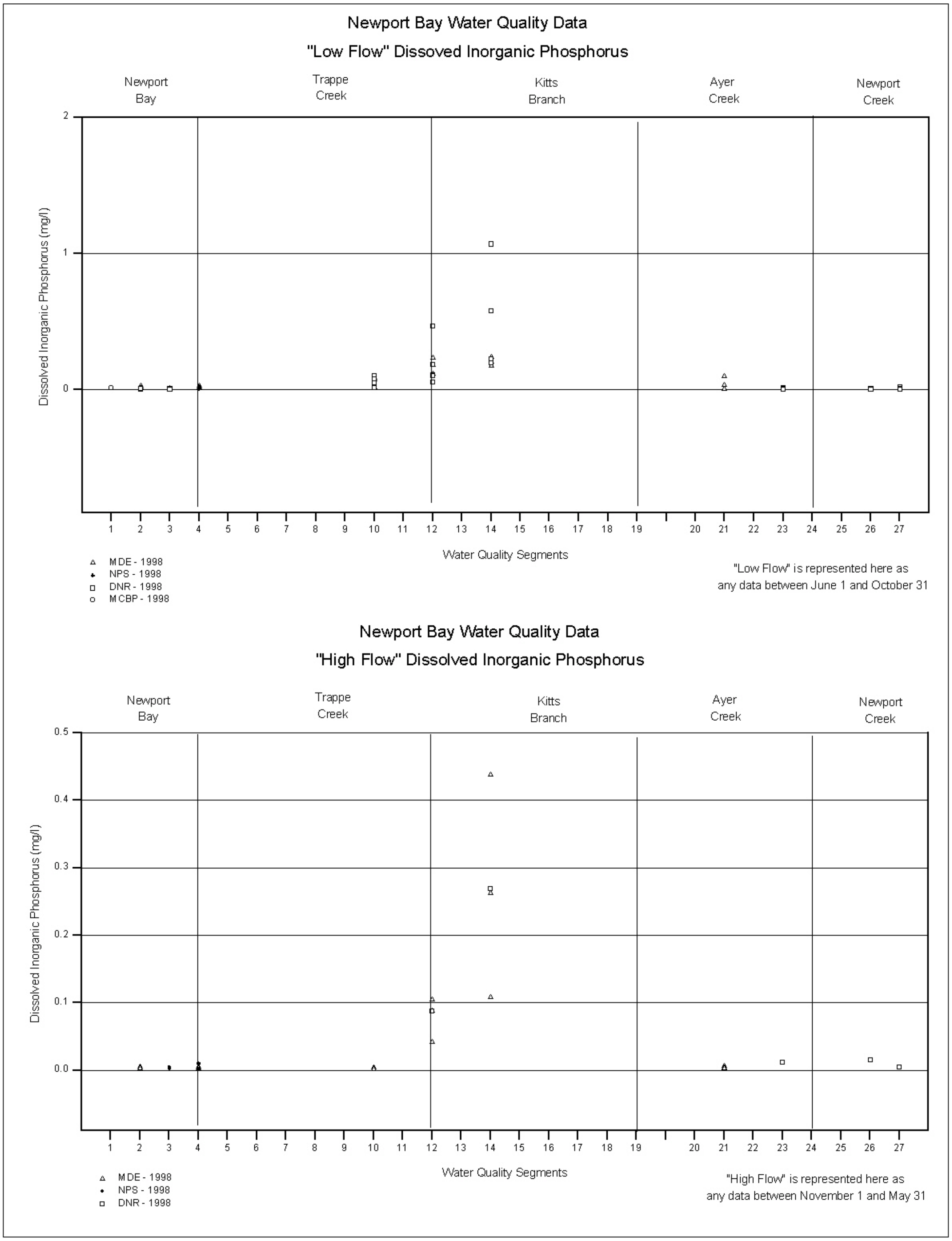

Figure A6: Profile of Dissolved Inorganic Phosphorus Data

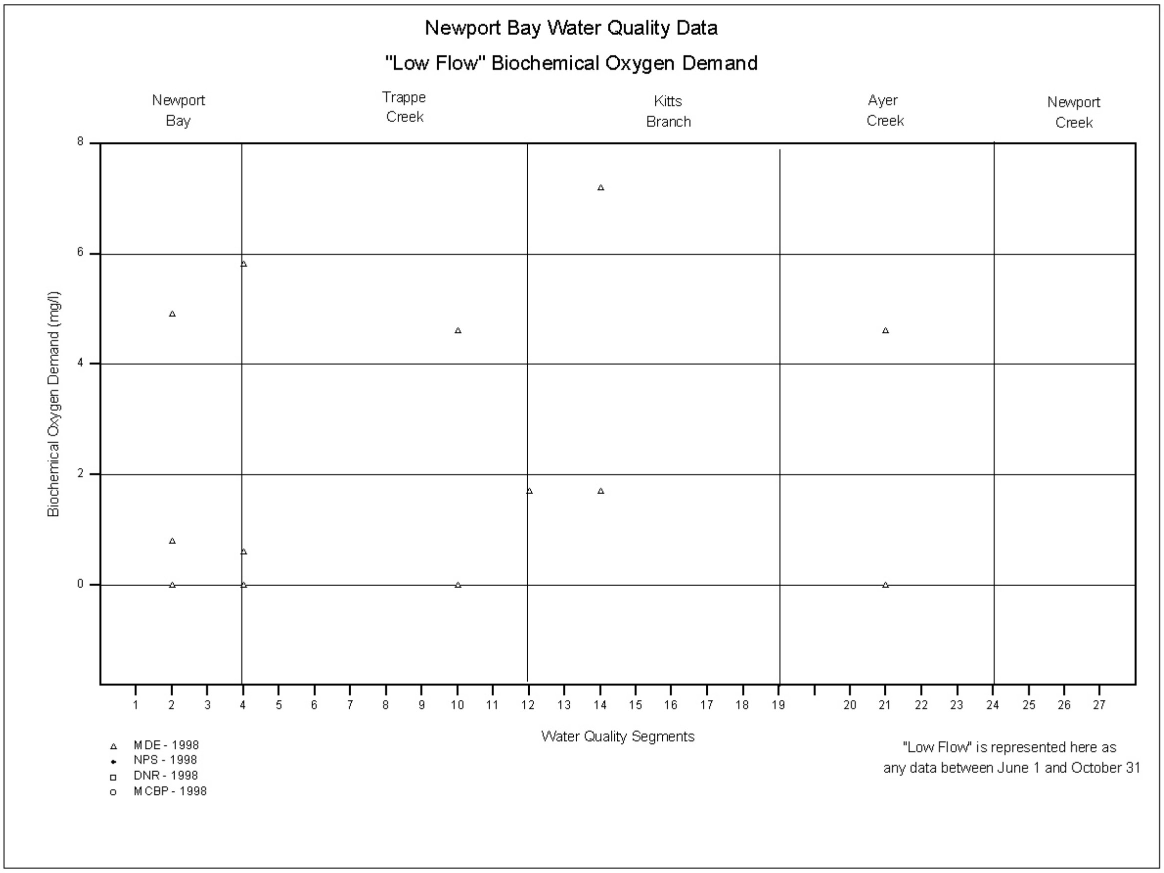

Figure A7: Profile of Biochemical Oxygen Demand Data

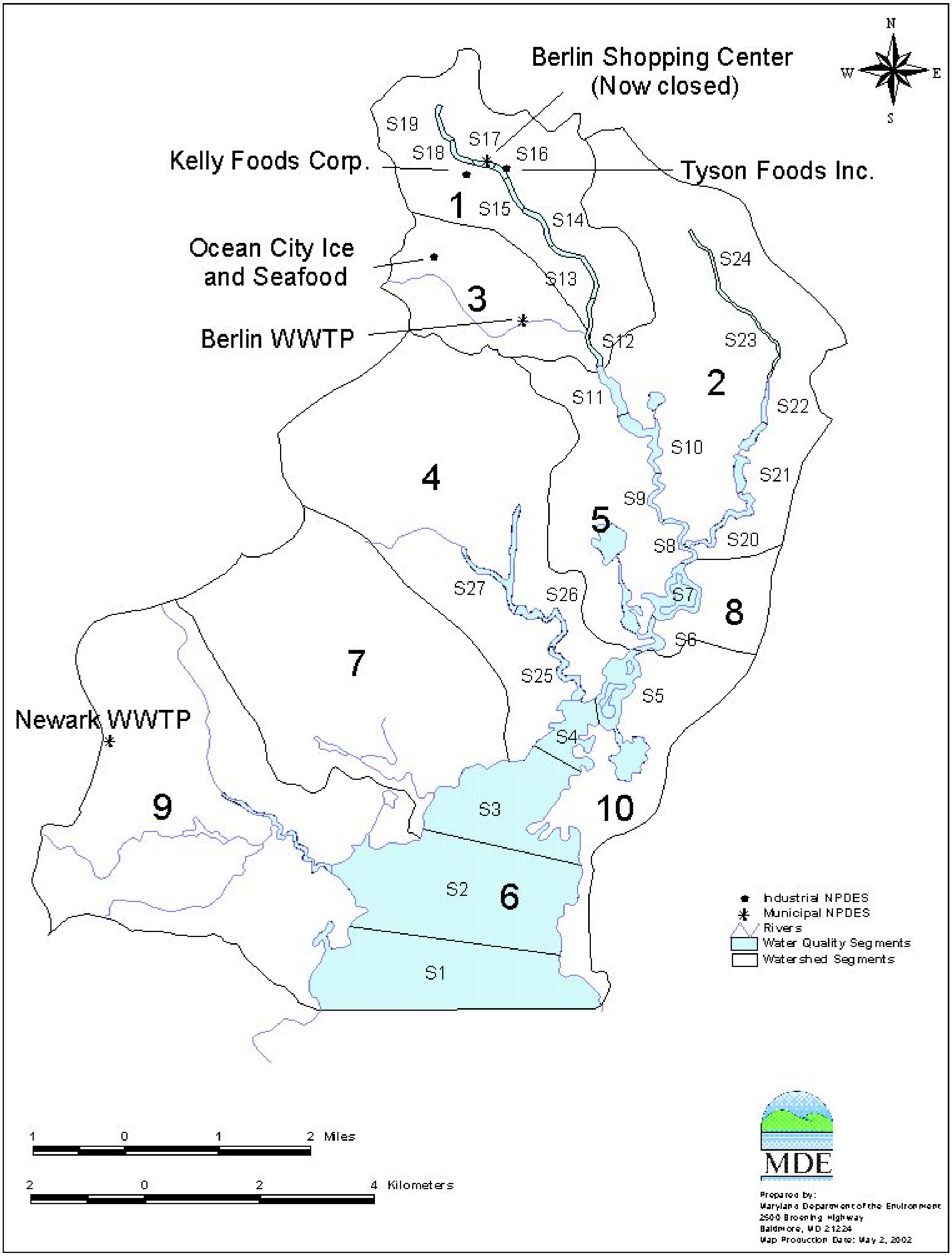

Figure A8: NBEM Segmentation – Watershed and Water Quality

Table A3: Water Quality Model Segment Volumes and Depths

Water Quality Segments	Volume m^3	Depth m
1	7577070	1.73
2	9065718	1.73
3	5565300	1.42
4	1110970	1.17
5	982032	1.16
6	135576	1.23
7	370263	1.25
8	151642.9	1.24
9	142414.1	1.23
10	265432.2	1.21
11	183582	1.10
12	41444.6	0.84
13	5618	0.67
14	4115.5	0.67
15	2060	0.67
16	1715.9	0.67
17	1724.6	0.67
18	2800.3	0.67
19	3457.9	0.67
20	250640	1.27
21	157518.8	1.20
22	51285	0.95
23	18217.7	0.74
24	6532.5	0.67
25	124960	0.80
26	114700	0.75
27	103740	0.70

Table A4: Water Quality Segment Pair Characteristic Lengths, Interfacial Areas, and Dispersion Coefficients

Water Quality Segment Pairs		Interfacial Area m^2	Characteristic Length m	Dispersion Coefficient m^2/sec
0	1	8107	1020.0	28.0
1	2	6750	1311.0	25.0
2	3	4568	1776.0	22.0
3	4	1140	1647.5	15.0
4	5	512	2169.5	15.0
5	6	144	2001.0	15.0
6	7	125	1991.0	12.0
7	8	124	2150.5	9.0
8	9	104.6	1231.0	6.0
9	10	146.4	1288.0	3.0
10	11	222	1371.5	1.0
11	12	60	1295.0	0.5
12	13	4.4	1289.0	0.5
13	14	4.4	1117.5	0.0
14	15	4.4	709.0	0.0
15	16	4.4	433.5	0.0
16	17	4.4	395.0	0.0
17	18	4.4	519.5	0.0
18	19	4.4	748.5	0.0
19	0	4.4	794.0	0.0
8	20	124	1096.3	8.0
20	21	117	1717.5	6.0
21	22	115.5	1067.5	3.0
22	23	16	1285.0	0.5
23	24	4.4	1645.0	0.0
24	0	4.4	1500.0	0.0
4	25	112	950.0	9.0
25	26	64	1450.0	7.0
26	27	91	1520.0	5.0
27	28	42	1560.0	5.0

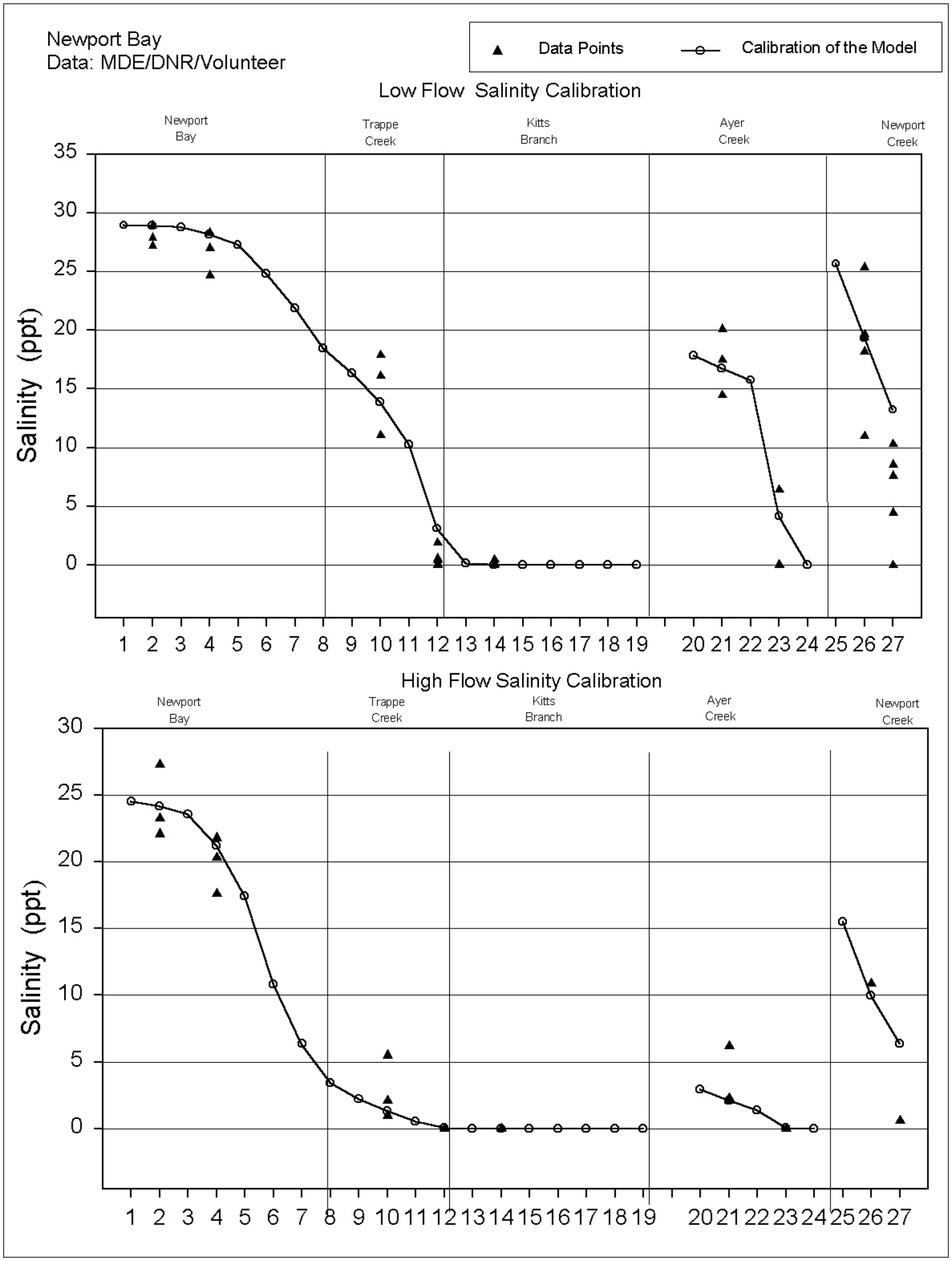

Figure A9: Low Flow and High Flow Calibrations of the Model for Salinity

Table A5: Freshwater Flows to the Newport Bay
(does not include flow from direct groundwater discharge)

Sub-watershed flows	Area km2	Low flow m^3/sec	High Flow m^3/sec	7Q10 Flow m^3/sec	Spring Flow m^3/sec	Winter Flow m^3/sec
1	10.968	0.0185	0.1827	0.0067	0.1441	0.2069
2	18.630	0.0314	0.3103	0.0114	0.2447	0.3515
3	5.899	0.0100	0.0982	0.0036	0.0775	0.1113
4	21.207	0.0358	0.3532	0.0130	0.2785	0.4002
5	7.427	0.0125	0.1237	0.0046	0.0975	0.1401
6	17.508	0.0295	0.2916	0.0108	0.2300	0.3304
7	17.568	0.0296	0.2926	0.0108	0.2307	0.3315
8	2.461	0.0042	0.0410	0.0015	0.0323	0.0464
9	23.302	0.0393	0.3881	0.0143	0.3061	0.4397
10	6.520	0.0110	0.1086	0.0040	0.0856	0.1230

Table A6: Contributing Watersheds to each Model Segment, and Flows for the Segments

Flows to Water Quality Segment	Sub-watersheds	Low flow m^3/sec	High Flow m^3/sec	7Q10 Flow m^3/sec	Spring flow flow, m^3/sec	Winter Flow flow, m^3/sec
2	6, 9, 10	0.0585	0.5778	0.0213	0.4556	0.6546
3	6, 7, 10	0.0414	0.4090	0.0151	0.3225	0.4633
5	4, 6, 10	0.0094	0.0932	0.0034	0.0735	0.1055
6	5, 6, 8	0.0065	0.0638	0.0024	0.0503	0.0723
7	6, 8	0.0037	0.0363	0.0013	0.0286	0.0411
9	2, 5, 6	0.0037	0.0362	0.0013	0.0285	0.0410
10	2, 5, 6	0.0039	0.0380	0.0014	0.0300	0.0431
11	2, 5, 6	0.0037	0.0369	0.0014	0.0291	0.0419
12	1, 3	0.0118	0.1165	0.0043	0.0919	0.1320
13	1	0.0037	0.0365	0.0013	0.0288	0.0414
14	1	0.0019	0.0183	0.0007	0.0144	0.0207
15	1	0.0037	0.0365	0.0013	0.0288	0.0414
16	1	0.0019	0.0183	0.0007	0.0144	0.0207
17	1	0.0019	0.0183	0.0007	0.0144	0.0207
18	1	0.0019	0.0183	0.0007	0.0144	0.0207
19	1	0.0019	0.0183	0.0007	0.0144	0.0207
20	2	0.0047	0.0465	0.0017	0.0367	0.0527
21	2	0.0047	0.0465	0.0017	0.0367	0.0527
22	2	0.0031	0.0310	0.0011	0.0245	0.0352
23	2	0.0075	0.0745	0.0027	0.0587	0.0844
24	2	0.0085	0.0838	0.0031	0.0661	0.0949
25	4	0.0250	0.2473	0.0091	0.1950	0.2801
26	4	0.0036	0.0353	0.0013	0.0279	0.0400
27	4	0.0054	0.0530	0.0020	0.0418	0.0600

Table A7: Point Source Loads used in the High Flow and Low Flow Calibrations of the NBEM

	FLOW	NH3	NO23	TON	PO4	OP	CBODu	DO
Low Flow Loads	*mgd*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*
Tyson Foods	0.519	1.013	9.687	2.814	0.954	1.010	16.106	13.63
Kelly Foods	0.006	0.007	0.009	0.008	0.002	0.003	0.112	0.23
Berlin Shopping Center	0.002	0.009	0.028	0.002	0.020	0.004	0.137	0.05
High Flow Loads								
Tyson Foods	0.729	4.278	71.768	7.775	1.449	0.483	28.270	24.57
Kelly Foods	0.006	0.007	0.009	0.008	0.002	0.003	0.112	0.23
Berlin Shopping Center	0.003	0.018	0.026	0.004	0.025	0.005	0.200	0.08
Newark WWTP	0.061	0.861	0.824	0.189	0.582	0.111	7.408	2.21
Berlin WWTP	0.411	5.753	26.745	3.732	0.404	0.078	34.288	10.76

Table A8: Low Flow Nonpoint Source Loads and Concentrations used in the Calibration of the Model
(include loads from the groundwater and the atmospheric deposition)

Water Quality Segments	NH4 kg/d	NO3 kg/d	PO4 kg/d	Chl*a* μg/l	CBOD mg/l	DO mg/l	ON kg/d	OP kg/d
1	0.009*	0.009*	0.030*	14.0	2.7	5.7	1.198*	0.059*
2	3.327	40.390	0.110	17.1	0.0	5.6	7.359	0.075
3	1.185	22.313	0.078	17.1	3.3	5.6	2.869	0.053
5	0.284	5.159	0.018	17.1	3.3	5.6	0.682	0.012
6	0.169	3.393	0.012	17.1	3.3	5.6	0.415	0.008
7	0.171	2.336	0.007	17.1	3.3	5.6	0.387	0.005
9	0.036	1.604	0.013	17.1	3.3	5.6	0.116	0.005
10	0.094	1.987	0.014	17.1	3.3	5.6	0.234	0.005
11	0.051	1.717	0.014	17.1	3.3	5.6	0.148	0.005
12	0.043	3.164	0.054	8.1	3.3	6.6	0.287	0.035
13	0.014	1.337	0.013	8.1	3.3	5.6	0.072	0.005
14	0.007	0.668	0.007	8.1	3.3	5.6	0.036	0.002
15	0.014	1.337	0.013	8.1	3.3	5.6	0.072	0.005
16	0.007	0.668	0.007	8.1	3.3	5.6	0.036	0.002
17	0.007	0.668	0.007	8.1	3.3	5.6	0.036	0.002
18	0.007	0.668	0.007	8.1	3.3	5.6	0.036	0.002
19	0.007	0.668	0.007	8.1	3.3	5.6	0.036	0.002
20	0.064	2.157	0.017	17.1	3.3	5.6	0.184	0.006
21	0.066	2.168	0.017	17.1	3.3	5.6	0.188	0.006
22	0.027	1.354	0.011	17.1	3.3	5.6	0.091	0.004
23	0.028	2.724	0.027	17.1	3.3	5.6	0.147	0.010
24	0.031	3.065	0.031	17.1	3.3	5.6	0.165	0.011
25	0.129	10.335	0.090	8.1	3.3	5.6	0.559	0.032
26	0.053	1.661	0.013	8.1	3.3	5.6	0.149	0.005
27	0.086	2.526	0.019	8.1	3.3	5.6	0.236	0.007

*Note: * All these values are in mg/l*

Table A9: High Flow Nonpoint Source Loads and Concentrations used in the Calibration of the Model
(include loads from the groundwater and the atmospheric deposition)

Water Quality Segments	NH4 kg/d	NO3 kg/d	PO4 kg/d	Chl*a* mg/l	CBOD mg/l	DO mg/l	ON kg/d	OP kg/d
1	0.009*	0.004*	0.016*	8.1	3.3	8.1	0.734*	0.017*
2	8.420	237.031	2.090	1.1	3.3	9.2	20.791	1.974
3	3.357	159.112	1.281	1.1	3.3	9.2	13.232	0.811
5	0.796	36.351	0.294	1.1	3.3	9.2	3.032	0.192
6	0.487	24.695	0.197	1.1	3.3	9.2	2.043	0.118
7	0.445	14.620	0.125	1.1	3.3	9.2	1.259	0.105
9	0.144	13.560	0.102	1.1	3.3	9.2	1.083	0.037
10	0.276	14.678	0.116	1.1	3.3	9.2	1.210	0.067
11	0.179	13.962	0.106	1.1	3.3	9.2	1.125	0.045
12	0.182	12.388	0.875	4.7	3.3	9.2	0.852	0.297
13	0.058	6.595	0.683	1.1	3.3	9.2	0.415	0.209
14	0.029	3.298	0.353	1.1	3.3	9.2	0.208	0.093
15	0.058	6.595	0.705	1.1	3.3	9.2	0.415	0.186
16	0.029	3.298	0.353	1.1	3.3	9.2	0.208	0.093
17	0.029	3.298	0.353	1.1	3.3	9.2	0.208	0.093
18	0.029	3.298	0.353	1.1	3.3	9.2	0.208	0.093
19	0.029	3.298	0.353	1.1	3.3	9.2	0.208	0.093
20	0.224	17.580	0.134	1.1	3.3	9.2	1.416	0.057
21	0.228	17.596	0.134	1.1	3.3	9.2	1.418	0.058
22	0.114	11.604	0.086	1.1	3.3	9.2	0.924	0.030
23	0.193	24.322	0.201	1.1	3.3	9.2	2.171	0.053
24	0.217	27.363	0.227	1.1	3.3	9.2	2.442	0.060
25	0.721	91.836	0.675	1.1	3.3	9.2	7.254	0.195
26	0.180	13.374	0.102	1.1	3.3	9.2	1.080	0.045
27	0.284	20.110	0.154	1.1	3.3	9.2	1.628	0.071

*Note: * All these values are in mg/l*

Table A10: Estimated Current Spring Nonpoint Source Loads and Concentrations
(include loads from the groundwater and the atmospheric deposition)

Water Quality Segments	NH4 kg/d	NO3 kg/d	PO4 kg/d	Chl*a* mg/l	CBOD mg/l	DO mg/l	ON kg/d	OP kg/d
1	0.009*	0.009*	0.030*	14.0	2.7	5.7	1.198*	0.059*
2	4.392	122.051	7.118	1.1	3.3	9.2	12.258	1.882
3	1.671	72.080	4.918	1.1	3.3	9.2	5.583	1.300
5	0.382	14.786	0.846	1.1	3.3	9.2	1.196	0.224
6	0.248	11.933	0.870	1.1	3.3	9.2	0.884	0.230
7	0.221	6.201	0.283	1.1	3.3	9.2	0.607	0.075
9	0.072	6.493	0.527	1.1	3.3	9.2	0.372	0.139
10	0.143	7.351	0.551	1.1	3.3	9.2	0.529	0.146
11	0.093	7.072	0.551	1.1	3.3	9.2	0.435	0.146
12	0.111	7.579	0.748	4.7	3.3	9.2	0.522	0.254
13	0.048	5.461	0.572	1.1	3.3	9.2	0.344	0.175
14	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
15	0.048	5.461	0.590	1.1	3.3	9.2	0.344	0.156
16	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
17	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
18	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
19	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
20	0.115	8.702	0.718	1.1	3.3	9.2	0.533	0.190
21	0.117	8.714	0.718	1.1	3.3	9.2	0.538	0.190
22	0.058	5.711	0.479	1.1	3.3	9.2	0.320	0.127
23	0.097	10.927	1.149	1.1	3.3	9.2	0.688	0.304
24	12.222	12.293	4.235	1.1	3.3	9.2	6.830	3.457
25	0.323	40.503	3.177	1.1	3.3	9.2	2.080	0.840
26	0.089	6.317	0.471	1.1	3.3	9.2	0.395	0.125
27	0.140	9.280	0.695	1.1	3.3	9.2	0.592	0.184

*Note: * All these values are in mg/l*

Table A11: Estimated Current Winter Nonpoint Source Loads and Concentrations

(include loads from the groundwater and the atmospheric deposition)

Water Quality Segments	NH4 kg/d	NO3 kg/d	PO4 kg/d	Chl*a* mg/l	CBOD mg/l	DO mg/l	ON kg/d	OP kg/d
1	0.009*	0.009*	0.030*	14.0	2.7	5.7	1.198*	0.059*
2	7.785	149.187	8.247	1.1	3.3	9.2	10.083	2.181
3	2.757	79.927	4.918	1.1	3.3	9.2	4.583	1.300
5	0.644	16.597	0.846	1.1	3.3	9.2	0.954	0.224
6	0.401	13.130	0.870	1.1	3.3	9.2	0.743	0.230
7	0.387	7.005	0.283	1.1	3.3	9.2	0.454	0.075
9	0.095	7.074	0.527	1.1	3.3	9.2	0.351	0.139
10	0.226	8.054	0.551	1.1	3.3	9.2	0.452	0.146
11	0.133	7.690	0.551	1.1	3.3	9.2	0.399	0.146
12	0.111	7.579	0.748	4.7	3.3	9.2	0.522	0.254
13	0.048	5.461	0.572	1.1	3.3	9.2	0.344	0.175
14	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
15	0.048	5.461	0.590	1.1	3.3	9.2	0.344	0.156
16	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
17	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
18	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
19	0.024	2.730	0.295	1.1	3.3	9.2	0.172	0.078
20	0.163	9.479	0.718	1.1	3.3	9.2	0.488	0.190
21	0.168	9.494	0.718	1.1	3.3	9.2	0.491	0.190
22	0.074	6.203	0.479	1.1	3.3	9.2	0.306	0.127
23	0.097	10.927	1.149	1.1	3.3	9.2	0.688	0.304
24	0.109	12.293	1.293	1.1	3.3	9.2	0.774	0.342
25	0.361	44.286	3.177	1.1	3.3	9.2	2.045	0.840
26	0.131	6.914	0.471	1.1	3.3	9.2	0.357	0.125
27	0.209	10.186	0.695	1.1	3.3	9.2	0.529	0.184

*Note: * All these values are in mg/l*

Table A12: Environmental Parameters used in the Low Flow and High Flow Calibrations of the Model

Water Quality	Temperature (^oc)		Salinity (ppt)		Extinction Coeff. (m^{-1})		FNH_4	FPO_4	SOD (g O_2/m^2 day)	
Segments	Low flow	High flow	Low flow	High flow	Low flow	High flow	mg N/m^2d	mg P/m^2d	Low flow	High flow
1	25.4	15	28.6	24.6	5.5	2.8	24	0.48	2	1
2	25.4	15	27.9	24.3	5.8	3.5	36	0.72	2.1	0.8
3	25.4	15	27.4	22.4	6	3.8	48	0.96	2.2	0.8
4	25.4	15	26.9	20.6	6	3.8	48	0.96	2.2	0.8
5	25.4	15	24.8	17.2	6	3.8	48	0.96	2.2	0.8
6	25.4	15	22.5	13.8	6	5.8	60	1.2	2.3	0.7
7	25.4	15	20.2	10.4	6	8.8	72	1.44	2.4	0.7
8	25.4	15	17.7	6.7	6	8.8	72	1.44	2.4	0.7
9	25.4	15	16.2	4.6	6	8.8	72	1.44	2.2	0.7
10	25.4	16	13.8	2.6	6	3.5	60	1.2	2.2	0.7
11	25.4	16	7.2	1.3	6.5	2.8	24	0.48	2.1	0.7
12	22.4	16	1.1	0.11	8.8	3.8	6	0.12	2	0.6
13	22.4	16	0.41	0	8.8	5.8	2.4	0.048	1.5	0.5
14	22.4	15	0	0	8.8	5.8	0	0	1	0.5
15	22.4	15	0	0	8.8	5.8	0	0	1	0.5
16	22.4	15	0	0	8.8	5.8	0	0	0.5	0.5
17	22.4	15	0	0	8.8	5.8	0	0	0.5	0.5
18	22.4	15	0	0	8.8	5.8	0	0	0.5	0.5
19	22.4	15	0	0	8.8	8.8	0	0	0.5	0.5
20	22.4	15	17.5	4.5	8.8	6.5	60	1.2	2.4	1.1
21	22.4	15	17.4	2.1	8.8	6.5	36	0.72	2.3	1.1
22	22.4	15	10.8	0.8	5.5	6.5	12	0.24	2	1
23	22.4	15	2.8	0	6	6.5	6	0.12	1.2	0.7
24	22.4	15	0	0	6	6.5	0	0	0.5	0.5
25	25.4	15	20.9	19.6	5.5	6.5	24	0.48	2.2	1
26	25.4	15	10.9	9.8	5.5	6.5	6	0.12	2.1	0.9
27	25.4	15	1.9	0.6	5.5	8.8	3.6	0.072	2	0.8

	Low flow	High flow
Solar Radiation (Langleys)	467	420
Photoperiod (fraction of a day)	0.57	0.55

Table A13: EUTRO5 Kinetic Coefficients

Constant	Code	Value
Nitrification rate	K12C	0.12 *day*-1 at 20^{o} C
temperature coefficient	K12T	1.08
Denitrification rate	K20C	0.07 *day*-1 at 20^{o} C
temperature coefficient	K20T	1.08
Saturated growth rate of phytoplankton	K1C	1.5 *day*-1 at 20^{o} C
temperature coefficient	K1T	1.06
Endogenous respiration rate	K1RC	0.105 *day*-1 at 20^{o} C
temperature coefficient	K1RT	1.045
Nonpredatory phytoplankton death rate	K1D	0.02 *day*-1
Phytoplankton Stoichometry		
Oxygen-to-carbon ratio	ORCB	2.67 $mg\ O_2/\ mg\ C$
Carbon-to-chlorophyll ratio	CCHL	25
Nitrogen-to-carbon ratio	NCRB	0.25 *mg N/mg C*
Phosphorus-to-carbon ratio	PCRB	0.025 $mg\ PO_4\text{-}P/\ mg\ C$
Half-saturation constants for phytoplankton growth		
Nitrogen	KMNG1	0.025 *mg* N / L
Phosphorus	KMPG1	0.001 *mg* P / P
Fraction of dead phytoplankton recycled to organic		
nitrogen	FON	1.0
phosphorus	FOP	0.1
Light Formulation Switch	LGHTS	1 = Di Toro
Saturation light intensity for phytoplankton	IS1	450. *Ly/day*
BOD deoxygenation rate	KDC	0.07 *day*-1 at 20^{o} C
temperature coefficient	KDT	1.05
Mineralization rate of dissolved organic nitrogen	K71C	0.005 *day*-1
temperature coefficient	K71T	1.08
Mineralization rate of dissolved organic phosphorus	K58C	0.15 *day*-1
temperature coefficient	K58T	1.00

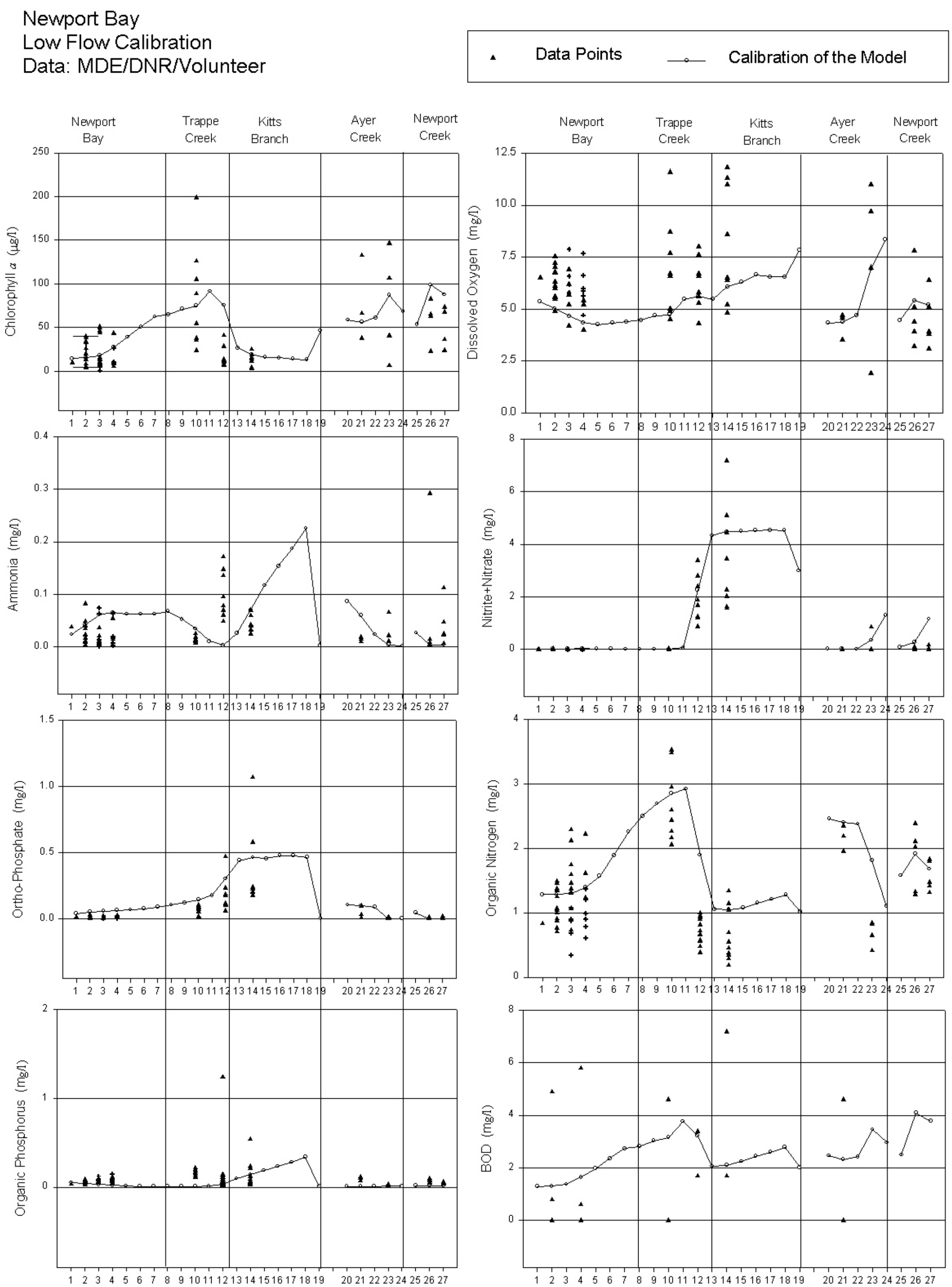

Figure A10: Low Flow Calibration of the Model

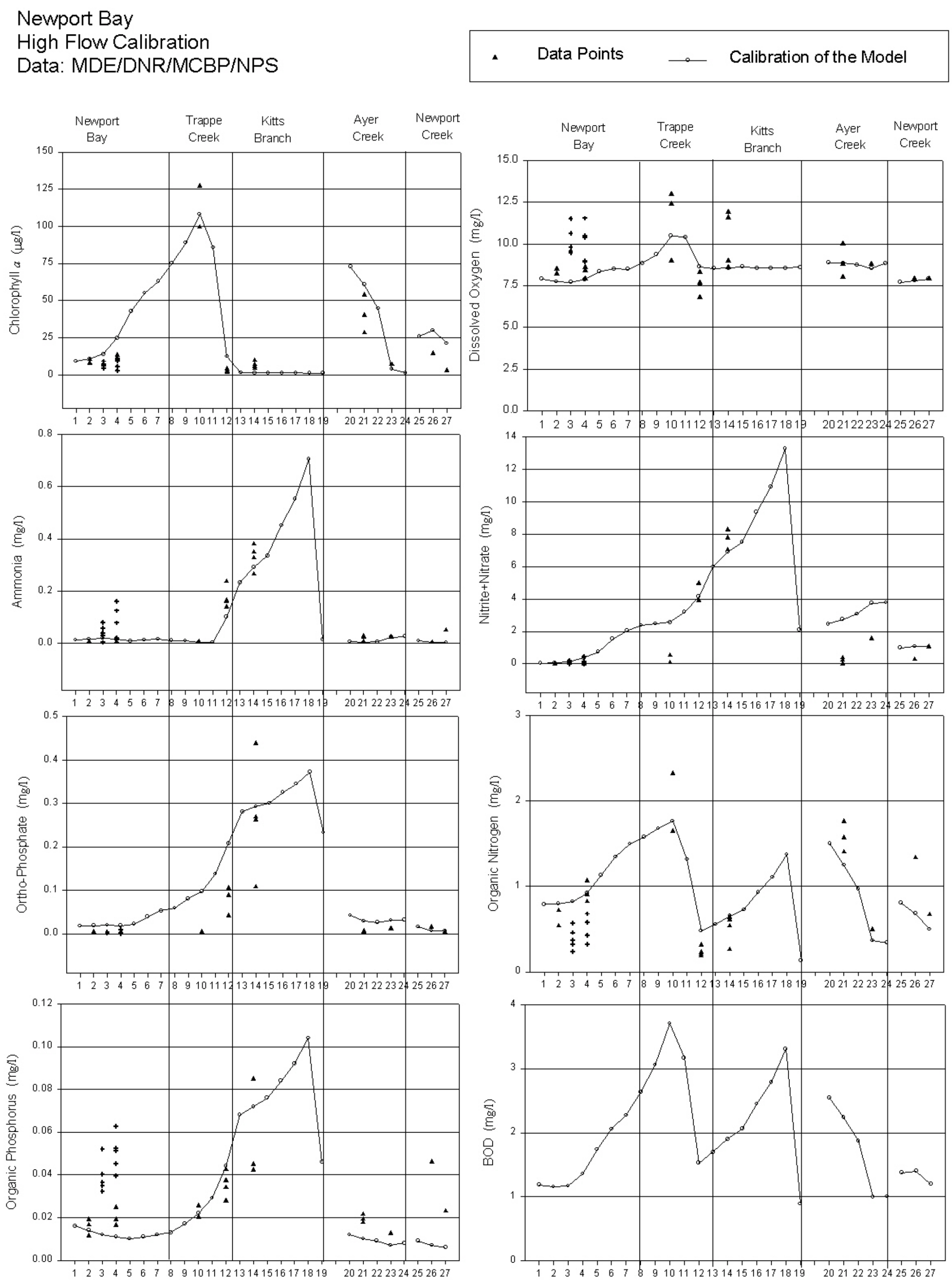

Figure A11: High Flow Calibration of the Model

Table A14: Maximum Point Source Loads used in Scenario 1, Scenario 2, & Scenario 3 (Baseline Scenarios)

Summer Flow	Flow	NH3	NO23	ON	TN	PO4	OrgP	TP	BOD5	DO
Baseline Loads	*mgd*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*
Tyson Food	0.8	3.632	11.321	0.451	15.403	0.735	0.779	1.514	18.144	21.017
Kelly Food	0.006	0.104	0.112	0.120	0.335	0.007	0.007	0.013	0.447	0.112

Spring Flow	Flow	NH3	NO23	ON	TN	PO4	OrgP	TP	BOD5	DO
Baseline Loads	*mgd*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*
Tyson Food	0.8	12.113	78.737	6.057	96.910	2.942	3.115	6.057	68.039	26.952
Kelly Food	0.006	0.007	0.009	0.008	0.025	0.002	0.003	0.005	0.067	0.232
Newark WWTP*	0.061	0.861	0.824	0.189	1.875	0.582	0.111	0.693	4.445	2.205

Winter Flow	Flow	NH3	NO23	ON	TN	PO4	OrgP	TP	BOD5	DO
Baseline Loads	*mgd*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*	*kg/d*
Tyson Food	0.8	4.694	78.737	8.530	91.960	2.942	3.115	6.057	68.039	26.952
Kelly Food	0.006	0.007	0.009	0.008	0.025	0.002	0.003	0.005	0.067	0.232
Newark WWTP*	0.061	0.861	0.824	0.189	1.875	0.582	0.111	0.693	4.445	2.205
Berlin WWTP	1.0	16.012	22.334	80.629	118.975	0.984	0.190	1.173	50.084	26.188

*This analysis does not explicitly address the water quality of Marshall Creek. The effect of Newark WWTP on Newport Bay is not discernable. Consequently, loads from Newark WWTP are being addressed in this analysis as part of the upstream background NPS load to Newport Bay that comes from Marshall Creek. Newark WWTP will be addressed explicitly when a future analysis is conducted for Marshall Creek. It should be noted that current permit requirements for Newark WWTP include zero allowable discharge for the months of June through August.

Table A15: Environmental Parameters used in the Spring and Winter Scenarios

Water Quality Segment	Temperature (^oC)	
	Spring Flow	Winter Flow
1	23	16
2	23	16
3	23	16
4	23	16
5	23	16
6	23	16
7	23	16
8	23	16
9	23	16
10	23	16
11	23	16
12	22.4	16
13	22.4	16
14	22.4	16
15	22.4	16
16	22.4	16
17	22.4	16
18	22.4	16
19	22.4	16
20	22.4	16
21	22.4	16
22	22.4	16
23	22.4	16
24	22.4	16
25	22.4	16
26	22.4	16
27	22.4	16

	Spring flow	Winter flow
Solar Radiation (Langleys)	432	343
Photoperiod (fraction of a day)	0.56	0.53

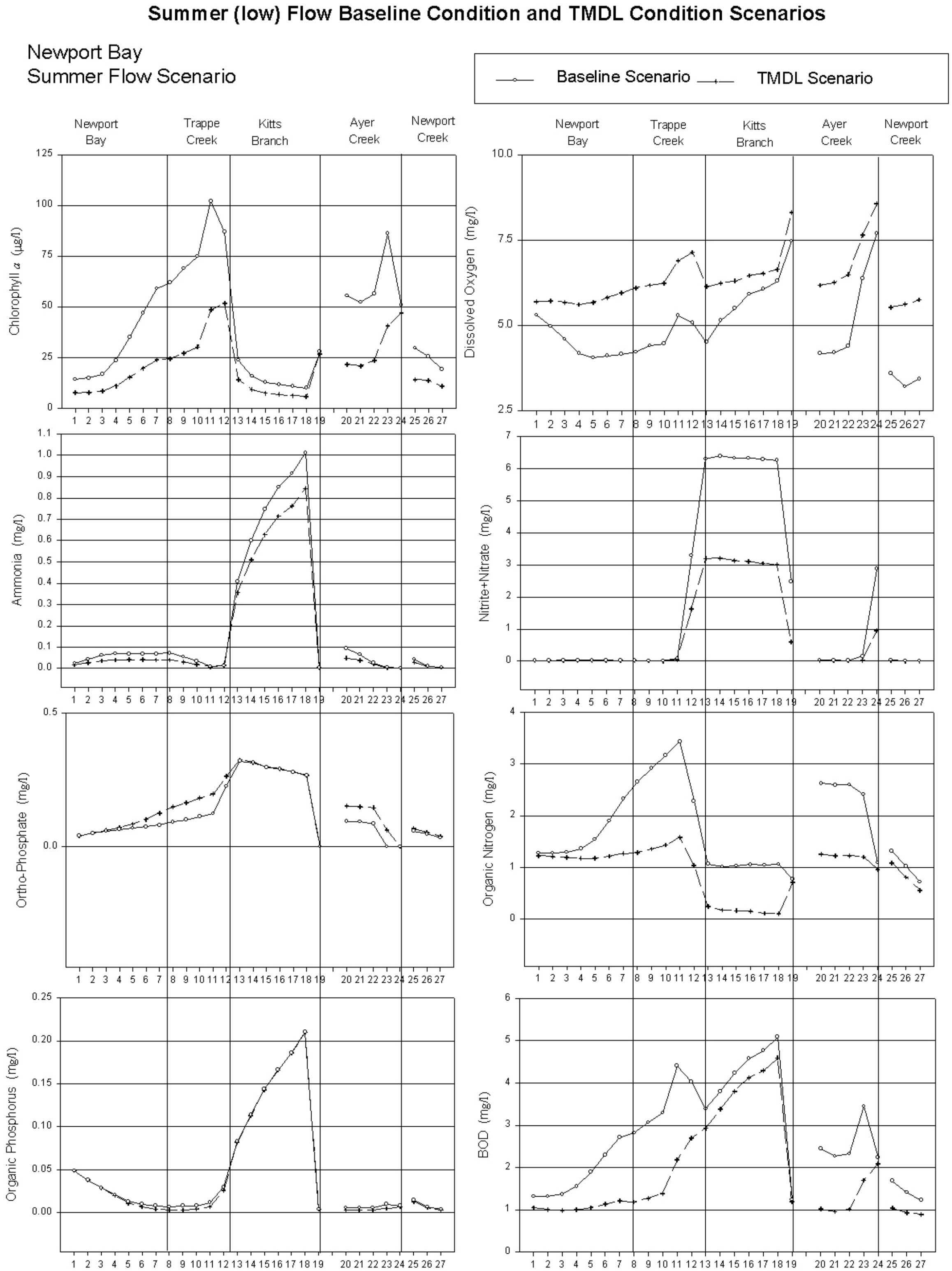

Figure A12: Low flow - Baseline Scenario and TMDL Scenario

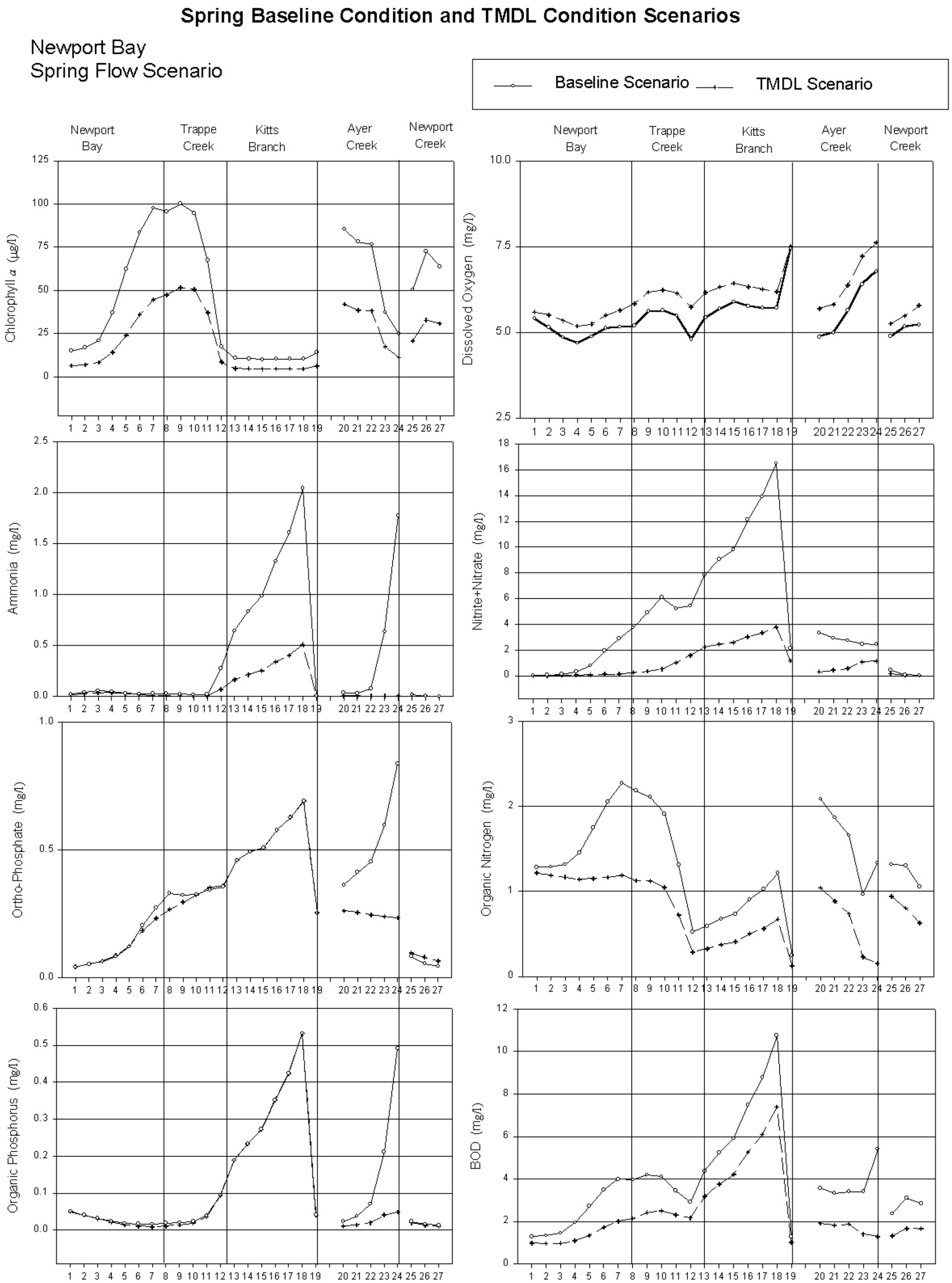

Figure A13: Spring Flow - Baseline Scenario and TMDL Scenario

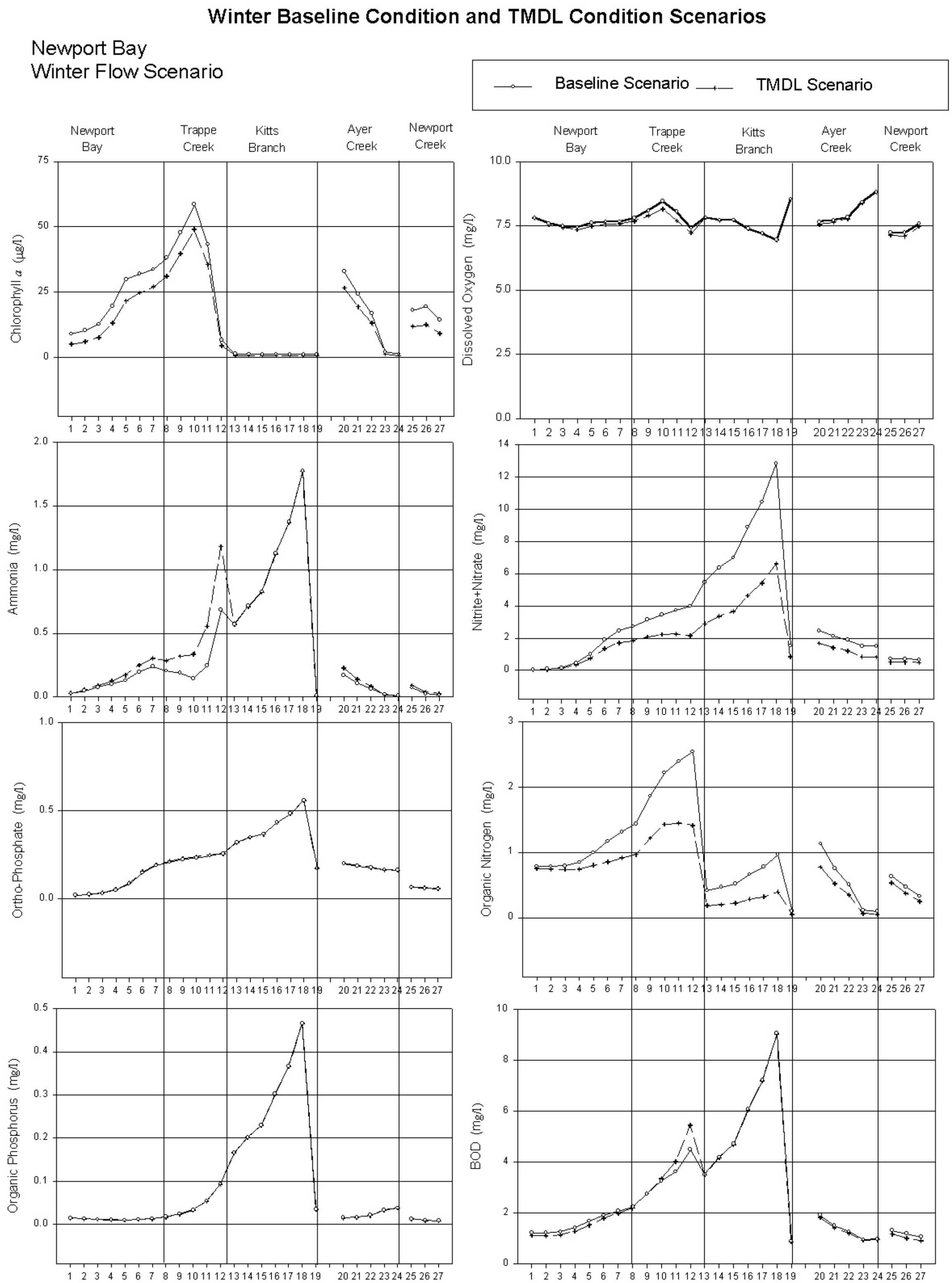

Figure A14: Winter Flow - Baseline Scenario and TMDL Scenario

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